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MANNED ORBITAL SYSTEMS CONCEPTS STUDY

BOOK 1 - EXECUTIVE SUMMARY

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-WEST

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FOREWORD

The basic MOSC Study encompassed a 9-month effort which examined the requirements for and established the definition of a cost-effective orbital facility concept capable of supporting extended manned operations in Earth orbit beyond those visualized for the 7- to 30-day Shuttle/Spacelab system. The study activity was organized into the following four tasks:

Task 1 Requirements Derivation

Task 2 Concepts Identification

Task 3 System Analysis and Definition

Task 4 Programmatics

In Task 1 the payload and mission requirements were examined for manned orbital systems with operational capabilities beyond those presently planned for the Shuttle/Spacelab program. These research activities were translated into characteristics of representative grouped payloads, including physical and operational parameters. The manned approach to research implementation was emphasized, as well as the lessons learned from previous Apollo and Skylab experience.

The second study task originally centered about the identification and definition of attached and free-flyer manned concepts to satisfy the requirements evolved from Task 1. Based upon the material presented in the first formal briefing, the study was redirected to conclude work on the attached mode of operation and concentrate the remaining effort on free-flying concepts.

Task 3 provided detailed definition of the baseline MOSC concept and the critical subsystem areas to a level required for subsequent programmatic analyses.

Task 4 developed project cost and schedule milestones related to the baseline concept in order to provide NASA with data useful for long-range planning activities and program analyses.

The study results are reported in four books. Book 1 presents an executive summary and overview of the study; Book 2 describes the derivation of requirements; Book 3 describes configuration development; and Book 4 describes the programmatic analyses.

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Section 1
INTRODUCTION

The anticipated reduction in cost and complexity of delivering scientific and technical personnel and payloads to space as provided by the Shuttle transporation system, currently under development, will mark the beginning of a new era in the exploration and utilization of space. As a consequence, facinating new opportunities for research and development programs present themselves. Recognizing this potential, the MOSC Study determined that a free-flying manned facility – space station – placed in permanent Earth orbit would be a viable and cost-effective adjunct to the basic Shuttle system. Together, the Shuttle and the free-flying manned orbital facility can offer unprecedented opportunities for the pursuit of knowledge and the application of space technology to the benefit of all mankind (Figure 1).

The free-flying manned orbital facility (as derived in the MOSC Study) would be supported at regular intervals by the Shuttle transportation system and would provide living and working quarters for a team of scientists and technicians. Such a facility would enable the scientific community to pursue

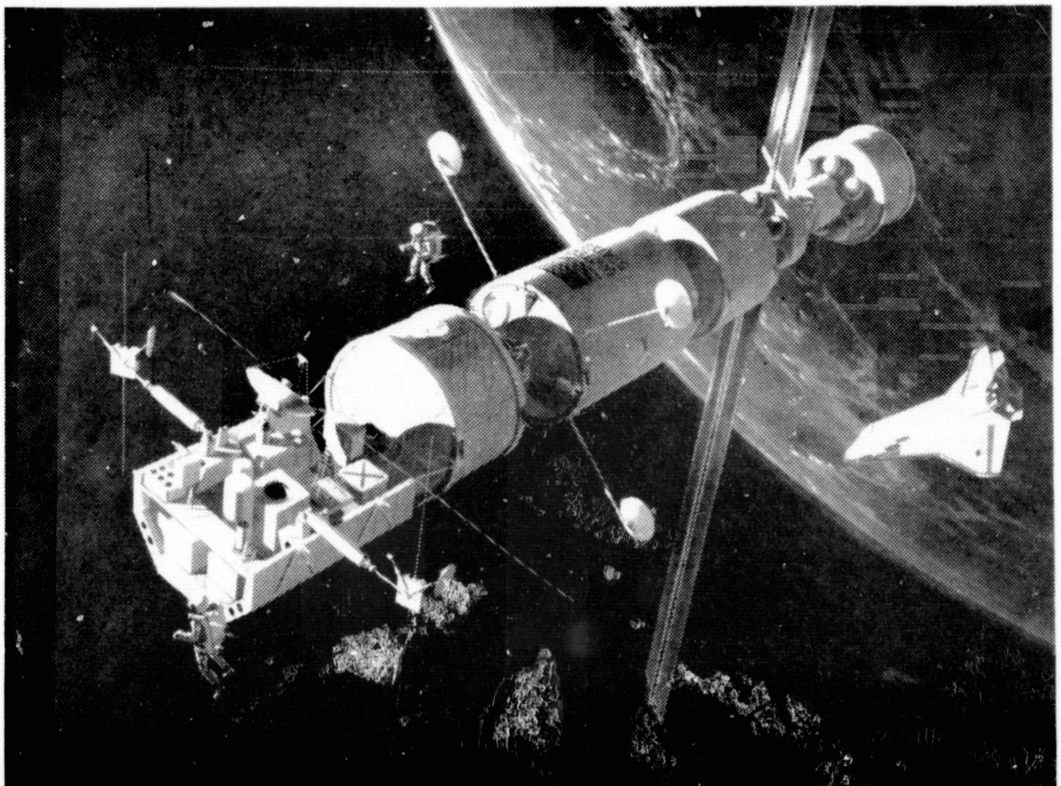

Figure 1. Free-Flying Manned Orbital Facility

programs directly related to the improvement of life on Earth — notably, Earth resources management, pollution control, global communications, weather forecasting for agriculture and disaster warning, manufacture of critical materials and medicines, and new energy sources for the world's growing needs.

Facilities that can significantly extend the available time that a team of scientists and technicians can stay in space, beyond the 7 to 30 days of the Orbiter flights, offer many potential advantages. For example, missions of longer duration allow time-dependent phenomena, such as physiological adaptation and physical growth processes, to be investigated. Furthermore, advantage can be taken of the improved efficiency that results from the crew learning to work more effectively with repeated trials and becoming acclimated to the space environment.

Longer missions offer potential savings by allowing less tightly constrained timelines and work schedules, which in turn are less subject to compromise if mission anomalies are encountered. Likewise, longer missions permit a given amount of work to be accomplished with fewer flights. Savings could be expected in ground operations from the reduction in the number and extent of turnarounds, refurbish cycles, and checkout operations. The realization of longer-duration space missions will have significant impact upon the effectiveness, the economics, and the breadth of possible research opportunities.

Fundamental to the success of these future missions is the enhancement of total system performance through the effective use of man and his capabilities.

The key guidelines for the study, as provided by NASA, and the major assumptions used in performing the analyses are as follows:

- Emphasis will be placed on manned missions longer than 30 days.
- Initial operational capability will be late 1984.
- All payloads will utilize STS as a launch vehicle.
- Available hardware — Orbiter, Spacelab, Skylab — will be utilized insofar as practical.
- JSC-07700, Vol. XIV, Revision C and Spacelab Accommodations Handbook will be used as the capability guides.
- Weight constraints per STS flight are 65,000 lb (29,484 kg) launch and 32,000 lb (14,515 kg) planned landing*.
- Modules for resources and habitability will be considered.
- Multiple flights and Shuttle RMS will be considered for assembly buildup.
- Payloads and payload groups as identified in the initial study task are to be accommodated.
- Payload (and/or module) accommodation will consider resupply of expendables, changeout at the experiment level, on-orbit servicing, and changeout at the module level (dedicated).

In addition to these ground rules it was also believed essential that the concept developed in the study be a logical and cost-effective step in the evolutionary path from the operational capability of the 7-day Shuttle/Spacelab system to the large, permanent, manned space bases in the future.

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*The English-to-metric and metric-to-English unit conversions in this report were calculated on the basis of the multipliers appearing in the U. S. Department of Commerce, National Bureau of Standards Special Publication 365, revised November 1972.

Section 2

REQUIREMENTS FOR EXTENDED-DURATION MISSIONS

The initial MOSC Study effort was directed toward the definition of the requirements that future research and applications programs may impose on manned space facilities. The critical facility sizing parameters include (1) crew size, (2) physical accommodations for payload equipment and supplies, and (3) operational characteristics, such as flight duration and orbital requirements. These requirements are major determinants of the subsystems that provide the onboard services and resources, such as electrical power, environmental control, propulsion, vehicle stabilization, communications, and data management. Likewise, the physical properties of the payloads influence space allocations, services to be provided, and operational considerations, such as deployment, pointing, orbital inclination and altitude operating regimes, STS flight and cargo requirements, and scheduling factors. The approach taken on the MOSC Study in establishing the payload requirements is described in the following paragraphs.

In the October 1973 Space Shuttle Traffic Model 12-year projection[(1)], 725 Shuttle flights were identified, of which 289 were Tug-related and 436 were classified as potential 7- to 30-day sortie flights. Of these 436 flights, 230 were found to prefer durations longer than 7 days if possible. These 230 7-day sortie flights, which are described in the Space Shuttle Payload Description Activity (SSPDA) documentation[(2)], served as the point of departure for the payload requirements analysis activity.

Altogether 103 potential payloads (which made up the 230 flights) were examined to determine the value of extended-capability missions in accomplishing the desired research objectives. Of these 103 payloads, NASA discipline specialists recommended 20 payloads as candidates for further analysis, based upon the scientific and technological activities described in the SSPDA. MDAC's MOSC Study team recommended an additional 26 payloads that appeared to be candidates for extended-duration missions on the basis of frequency and number of flights in the post-1984 time frame as described in the NASA mission model.

For the MOSC Study, the 46 payloads in turn were grouped into 19 payload combinations based on equipment commonality and operational requirements. These 19 payload combinations were then used to derive the operational and

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(1) The October 1973 Space Shuttle Traffic Model, Shuttle Utilization Planning Office, Program Development, MSFC, NASA TM X-64751, Revision 2, January 1974.

(2) Summarized NASA Payload Descriptions, Volume I Sortie Payload, Level A Data and Volume II Sortie Payloads, Level B Data, prepared by Program Development, Marshall Space Flight Center, National Aeronautics and Space Administration, July 1974 (preliminary).

design requirements for extended-duration missions. It should be noted that some of those payload/missions comprising the 57 payloads in the 206 flights that do not necessarily require extended stay times conceivably could also be flown advantageously on longer-duration missions if such capabilities were available. These 57 payloads, however, were not included in this analysis.

The 19 MOSC payload combinations that were used to provide the basic operational and design requirements for the remaining study tasks are listed in Table 1. Also shown are the major operational and physical characteristics and requirements for each payload described. The variance between the up and down payload weights is indicative of the expendables (cryogenics, disposable fluids, gases, etc.) utilized during a flight or mission segment. The crew manhours listed represent a measure of the relative involvement of the crew in support of the activities necessary to perform the tasks required in the payload operation.

The prime consideration in grouping the 46 payloads into these 19 categories was the commonality of the scientific objectives and/or application areas involved in the conduct of the orbital activities. Compatibility between and among the various disciplines was assessed in terms of classes of activities and common functions (i.e., remote sensing, in-situ investigations, environmental perturbations, whole-body research, etc.). Mission requirements, desired orbital altitude and inclinations, common environment requirements, and similar crew assignments and functions were also considered. In addition to equipment and operational factors, crew skills were evaluated in the groupings insofar as reasonable cross-training among the crew members for operating and servicing the payloads would appear feasible.

Table 1
MOSC PAYLOAD COMBINATIONS

Payload	Description	Crew Manhours	Weight (1,000 lb) Up	Weight (1,000 lb) Down	Volume (cu ft)	Avg Pwr (kW)	Mission Dur (days)	Alt (nmi)	Orbit Inclin (deg)
C1	IR Astronomy	1,454	31	25	4,500	1	80	216	28
C2	UV Astronomy	3,845	24	14	1,100	1	140	248	28
C3	Solar Observations	4,187	15	14	1,000	1	160	216	28
C4	Space Sciences 1	2,070	17	15	2,700	2	70	216	90
C5	Space Sciences 2	1,608	16	12	2,200	2	80	216	90
C6	Amps/Earth Science	3,280	24	14	1,900	2	120	200	90
C7	Space Technology	884	26	17	2,300	10	40	200	28
C8	Cloud Physics/Technology	882	15	13	2,000	1	50	100	28
C9	Earth Science 1	851	25	24	6,100	2	50	200	90
C10	Earth Science 2	690	26	26	6,000	2	80	200	90
C11	High-Energy Astronomy/Technology	1,118	20	20	1,200	1	70	135	28
C12	Life Science/Technology 1	8,289	100	66	13,300	10	400	200	28
C13	Life Science/Technology 2	4,039	81	60	10,600	6	200	200	28
C14	IR/UV Astronomy	1,427	45	17	2,000	2	120	162	90
C15	UV Astronomy, Advanced	585	24	16	1,000	1	50	162	90
C16	Cosmic Ray Laboratory	5,800	50	37	5,600	1	360	200	28
C17	LD Life Science Laboratory	23,200	39	34	2,600	8	720	200	28
C18	Advanced Technology	493	8	7	1,600	2	45	200	90
C19	Space Manufacturing	11,000	7	6	200	5	900	200	90

The correlation between the 46 original payloads and the 19 MOSC payload groups is summarized in Table 2.

Table 2
PAYLOADS CONSIDERED FOR MOSC MISSIONS (Page 1 of 2)

SSPDA No.	Payload Description	Assigned to MOSC Combination(s)
Astronomy		
AS-01-S	1.5-m Cryogenically Cooled IR Telescope	C-1
AS-03-S	Deep Sky UV Survey Telescope	C-2
AS-04-S	1-m Diffraction-Limited UV Optical Telescope	C-2
AS-08-S	Multipurpose 0.5-m Telescope	C-2
AS-10-S	Advanced XUV Telescope	C-2
AS-13-S	Solar Variation Photometer	C-3
AS-15-S	3.0-m Ambient Temperature IR Telescope	C-1
AS-19-S	Selected-Area Deep-Sky Survey Telescope	C-11
AS-31-S	Combined AS-01, -03, -04, -05-S	C-14
AS-54-S	Combined UV Payload (AS-03-S, -04-S)	C-15
High-Energy Astrophysics		
HE-14-S	Gamma-Ray Pallet	C-11
HE-19-S	Low-Energy X-Ray Telescope	C-11
HE-X-S	Cosmic-Ray Physics Laboratory	C-16
Solar Physics		
SO-01-S	Dedicated Solar Sortie Mission	C-3
Atmospheric and Space Physics		
AP-06-S	Atmospheric, Magnetospheric, and Plasmas in Space (AMPS)	C-4, C-5, C-6
Earth Observations		
EO-01-S	Zero-g Cloud Physics Laboratory	C-8
EO-05-S	Shuttle Imaging Microwave System (SIMS)	C-9, C-10
EO-06-S	Scanning Spectroradiometer	C-10
EO-07-S	Active Optical Scatterometer	C-6
Earth and Ocean Physics		
OP-02-S	Multifrequency Radar Land Imagery	C-9
OP-03-S	Multifrequency Dual-Polarized Microwave Radiometry	C-10
OP-04-S	Microwave Scatterometer	C-10
OP-05-S	Multispectral Scanning Imagery	C-6
OP-06-S	Combined Laser Experiment	C-9
Space Processing Applications		
SP-04-S	SPA No. 4 – General Purpose (Manned)	C-12
SP-05-S	SPA No. 5 – Dedicated (Manned)	C-12
SP-14-S	SPA No. 14 – Manned and Automated	C-7
SP-15-S	SPA No. 15 – Automated Furnace/Levitation	C-13
SP-16-S	SPA No. 16 – Biological/General (Manned)	C-12
SP-19-S	SPA No. 19 – Biological and Automated	C-13
SP-X1-S	Production of Surface Acoustic Wave Components	C-19
SP-X2-S	Production of High-Ductility Tungsten	C-19
SP-X3-S	Separation of Iso-enzymes	C-19
SP-X4-S	Production of Semiconductor Silicon Ribbon	C-19
Life Sciences		
LS-09-S	Life Sciences Shuttle Laboratory	C-12, C-13
LS-10-S	Life Sciences Carry-on Laboratories	C-12, C-13
LS-X-S	Life Sciences Long-Duration Laboratory	C-17

Table 2
PAYLOADS CONSIDERED FOR MOSC MISSIONS (Page 2 of 2)

SSPDA No.	Payload Description	Assigned to MOSC Combination(s)
Space Technology		
ST-04-S	Wall-less Chemistry + Molecular Beam (Facility No. 1)	C-7
ST-05-S	Superfluid He + Particle/Drop Positioning (Facility No. 2)	C-7
ST-06-S	Fluid Physics + Heat Transfer (Facility No. 3)	C-11
ST-21-S	ATL Payload No. 2 (Module + Pallet)	C-8
ST-22-S	ATL Payload No. 3 (Module + Pallet)	C-8
ST-23-S	ATL Payload No. 5 (Pallet Only)	C-18
Communications and Navigation		
CN-02-S	Communications/Navigation Shuttle Sortie Laboratory (4,000-lb version)	C-4
CN-04-S	Terrestrial Sources of Noise and Interference	C-5
CN-06-S	Communication Relay Tests	C-5

The crew skill requirements for each of the original payloads were defined in terms of 23 conventional categories (e.g., biochemist, agronomist, thermodynamicist, photo technician, biology technician, etc.).

Skill correlation matrices were then developed wherein the skill areas identified were cross-correlated, based on whether or not they were required by each of the payloads.

The correlation matrix was factor analyzed by the principal components solution, and seven factors (or groups of skills) were identified. These seven major categories representing multidisciplined or cross-trained individuals are listed (A to G) in Figure 2, and their assignments to the MOSC payload

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LEGEND

SKILL CATEGORIES

- A – EARTH SCIENCES
- B – LIFE SCIENCES
- C – METEOROLOGIST/ PHOTOGRAPHER
- D – MATERIAL SCIENCES
- E – PHYSICAL SCIENCES
- F – ENGINEERING TECHNICIAN
- G – ASTRONOMICAL SCIENCES

SKILLS REQUIRED FOR SINGLE PAYLOADS

A	B	C	D	E	F	G	PAYLOAD NO.
					X	X	1
					X	X	2
					X	X	3
				X	X		4
				X	X		5
X		X		X	X		6
			X	X	X		7
		X		X	X		8
X		X			X		9
X		X			X		10
			X		X	X	11
	X		X		X		12
	X		X		X		13
					X	X	14
					X	X	15
				X	X		16
	X				X		17
				X	X		18
			X		X		19

Figure 2. Payload Skills Requirements

groups are also indicated. When the payload groups are considered individually, no group requires more than four skills. Also, when combinations of two payload groups are considered, no group that might conceivably be combined requires more than four skill categories. This finding suggested that a four-man crew size might best represent the nominal or baseline case to use in the configuration sizing activity.

Inasmuch as the IOC date for the MOSC is late 1984, essentially 8 years are available before IOC for selecting and training the crew members. It is believed reasonable to cross-train individuals in several related skills during this time period so that one appropriately cross-trained specialist can perform the tasks that would normally require several specialists in the conventional sense. As a starting point in implementing this concept, the seven skill factors identified in Figure 2 might provide a useful reference around which to structure the crew skill development process.

Of all the payloads for which sufficiently detailed descriptive material was available, only one required a medical doctor per se. If it should be determined that a medical doctor is necessary, it is suggested that he be cross-trained in other related areas to maximize his overall usefulness and effectiveness in meeting other mission objectives. For example, with proper training he could not only function in the medical capacity but as a behavioral scientist and in the biological sciences as well.

In addition to the skills analysis, a second consideration in establishing a baseline crew size was the work output that might reasonably be expected from each crewman and the workload requirements that the various payload groups might place upon the crew. Although several payloads require that data be gathered continuously for long portions of the mission, no payload required continuous "around-the-clock" manual operation. Accordingly it was assumed that manual calibration, maintenance, and operation activities could be accomplished during normal working periods.

In estimating performance capabilities for individual crewmen, heavy reliance was placed upon Skylab experience. In Skylab missions about 57% of the available time was spent by the crewmen in personal activities, including sleeping and eating. About 33% of the time (8 hours per day per crewman) was available for experiment operations. These factors were used in subsequent payload requirements analyses to verify the number of crewmen required to support a given payload operation.

Another important consideration in determining the crew performance to be expected in future missions is the amount of learning that crewmen can be expected to achieve on extended missions. Learning in this case refers to the degree of adaptation to the zero-g environment and the attendant improvement in proficiency resulting from repeated performance of the same activity. Figure 3 presents the mean values of performance times for the initial, middle, and final third of three medical experiments: M092, "Inflight Lower Body Negative Pressure;" M171, "Metabolic Activity;" and M093, "Vectorocardiogram." When the data points are connected by the best-fitting straight lines, an estimate of the learning (performance improvement) experienced during the mission can be made. As noted, continuing performance of M092, M171, and M093 resulted in learning curve slopes of

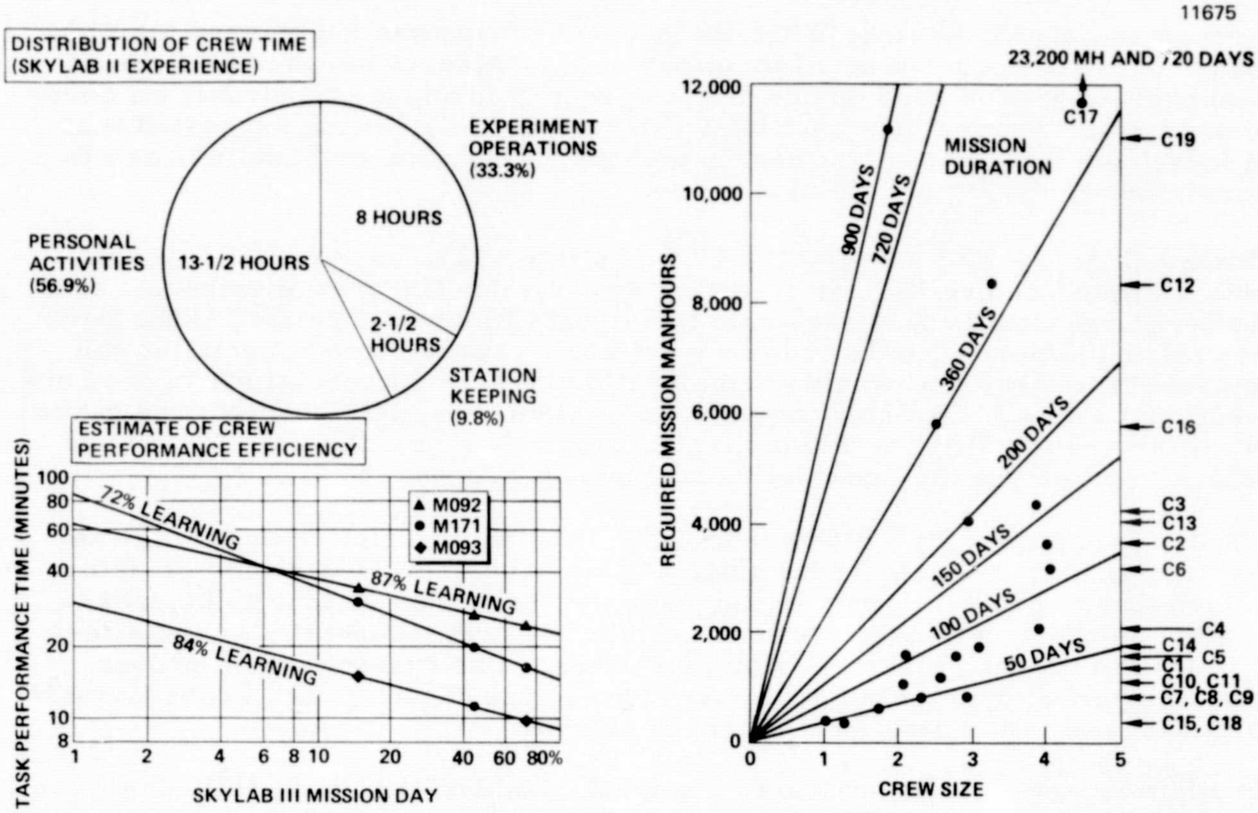

Figure 3. Crew Sizing Parameters

87, 72, and 84%, respectively. In light of this experience, it was believed reasonable to utilize a learning factor of 85% for MOSC missions when extrapolating the manhours required for a specific set of activities.

Also shown are the relationships between the manpower and mission duration requirements for each of the 19 MOSC payload groups. The family of curves representing mission durations of from 50 to 900 days was calculated using a factor of 8 hours per day per crewman available for payload operation, allowing one day in 7 as a day when no work would be scheduled (a day off), and considering improvement in onboard performance as a function of time in orbit to reflect an 85% learning curve. The points shown on the chart are plots of required manhours versus mission duration for each of the 19 payloads. It may be seen that here again a crew size of four appears sufficient to meet the demands of the 19 payloads under varying conditions of mission duration and workloads.

Since the investigation of a broad spectrum of research requirements suggested that a minimum crew size of four would provide an adequate reservoir of skills and more than the required number of on-orbit manhours to provide a flexible base for accommodating projected workloads, the crew size of four was established as the basic facility requirement. As demands increase, this core system could be expanded with additional modules and scientific and technical personnel.

The key design criteria derived from the 19 payload groups are summarized in Tables 3 and 4. It will be noted from Table 1 that only two payload combinations required more than 8 kW of power, whereas 90% required lesser amounts. Inasmuch as the two high-power-using combinations were originally defined in an unconstrained manner with regard to resources required, it was believed that these specific requirements could easily be reduced when the detailed design of the research facility was undertaken. Accordingly, it was recommended that 8 kW be the nominal payload power design point for the baseline MOSC, with supplemental power to be provided if later conditions warrant.

In making weight estimates for equipment items, actual weight numbers were used when available from existing hardware. For new hardware, weight estimates included a 10% contingency factor.

It can be anticipated that once a manned facility becomes available, many special uses will evolve. As an example, the versatility and availability of facilities for maintenance, repair, and modification could be of substantial

Table 3
MOSC DESIGN CRITERIA (FROM PAYLOAD REQUIREMENTS)

Flight Duration: Support 720-day missions

Crew Size: Up to four specialists per payload combination

Payload Power: 8 kW (supplemental to 10 kW)

Altitude/Inclination: 230 nmi/28.5°, 200 nmi/90°

Altitude Change Capability: ±95 nmi/28.5°

Platform Orientation: All attitudes, vehicle pointing to 0.1° accuracy, fine pointing to be achieved by instrument gimbaling

Onboard Disturbance Levels: $< 10^{-5}$ g

Contamination: Control to be equivalent to 100,000-class clean room

Data Management: Real-time 5 MHz; recover hard copy, film tapes, materials; closed-circuit TV

Communications: Real-time to payload control centers

Accommodation Features: Two-man EVA on routine basis
- Scientific/equipment airlock
- Payload equipment fully accessible
- Modularized payload carriers

Operational Features: Multiple/simultaneous active payloads
- Return all, part, or none of payload equipment
- Resupply payloads/rotate payload specialists
- Double ended, universal docking provisions

Table 4
MOSC DESIGN CRITERIA (FROM PROGRAM REQUIREMENTS)

Economy: Effective utilization of existing hardware

Schedule: IOC late 1984 at 28.5°, 1986 at 90°

Design Flexibility: Provide for evolutionary growth

Reliability: Nominal 5-year system life

Safety: Dual escape routes, all-mode rescue

Crew Rotation: 90-day nominal, 180-day maximum unless required for biomedical research

User Community: International utility, scientific, technological applications; industrial/commercial operations; space systems servicing and support; national defense options

Weight Estimates: Include 10% contingency on new hardware

value to potential users. Not only can individual payloads be serviced and maintained, but payloads can also be reconfigured in space. Logistic flights can provide necessary parts, as well as new equipment and supplies, for an essentially continuous operation. This continuity would be especially useful in pilot-plant and large-volume space-manufacturing operations.

Satellite servicing in orbit (Figure 4) is also a possible area for future development. On-site manned operations have the potential to simplify servicing, fault isolation, repair, refurbishment, and checkout.

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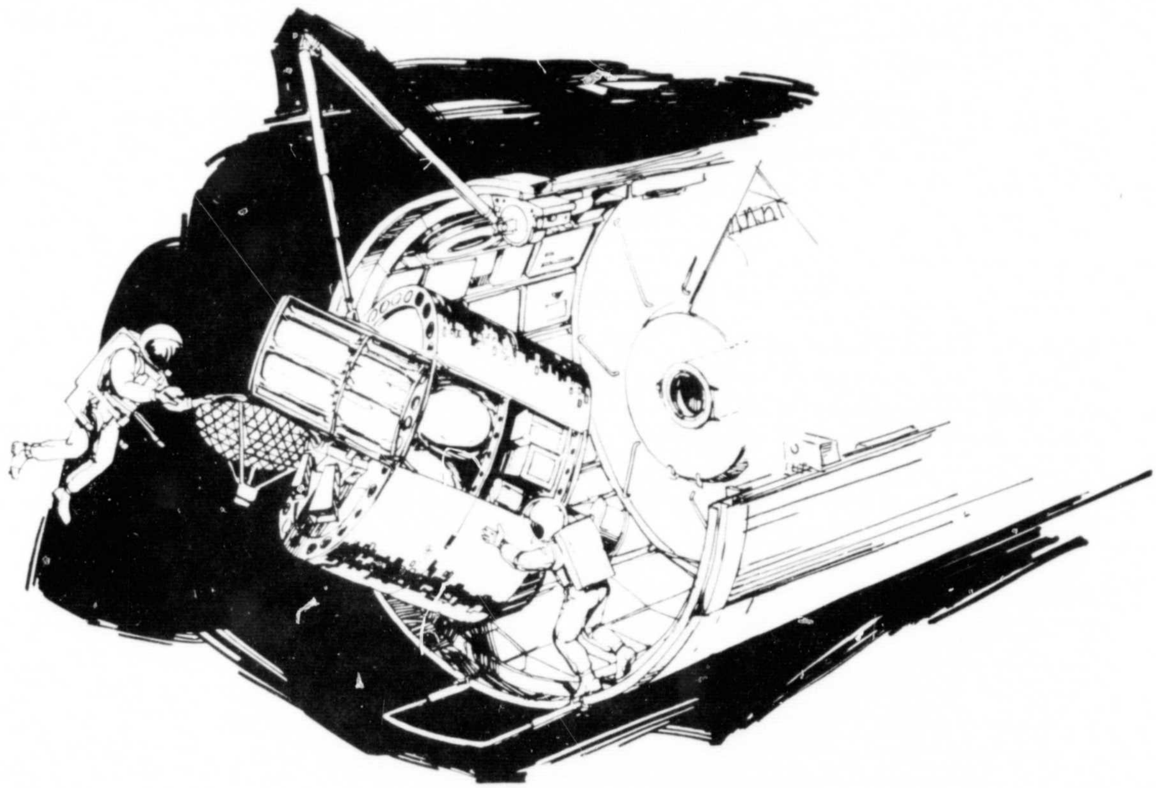

Figure 4. Satellite Servicing Operations

The capability to assemble large space structures (Figures 5 and 6) provides the opportunity to develop scientific and observational capabilities that are not obtainable on Earth. In addition to large-aperture radio telescopes, large antenna structures have applications in the fields of communication, media broadcasting, surveillance, and advanced power-transmission concepts.

The assembly of large antennas for mass communication or power transmission purposes, for example, would be greatly simplified by the availability of man to rig and deploy the structure. Structural members could even be formed in space; truss elements could be extruded, thereby requiring only the raw materials to be transported as cargo to the facility. The structure could be assembled with simple, sequential manual operations instead of complex automated or remotely controlled procedures.

The basic orbital facility must have the inherent flexibility and growth capability to accommodate new users and new needs as they are identified.

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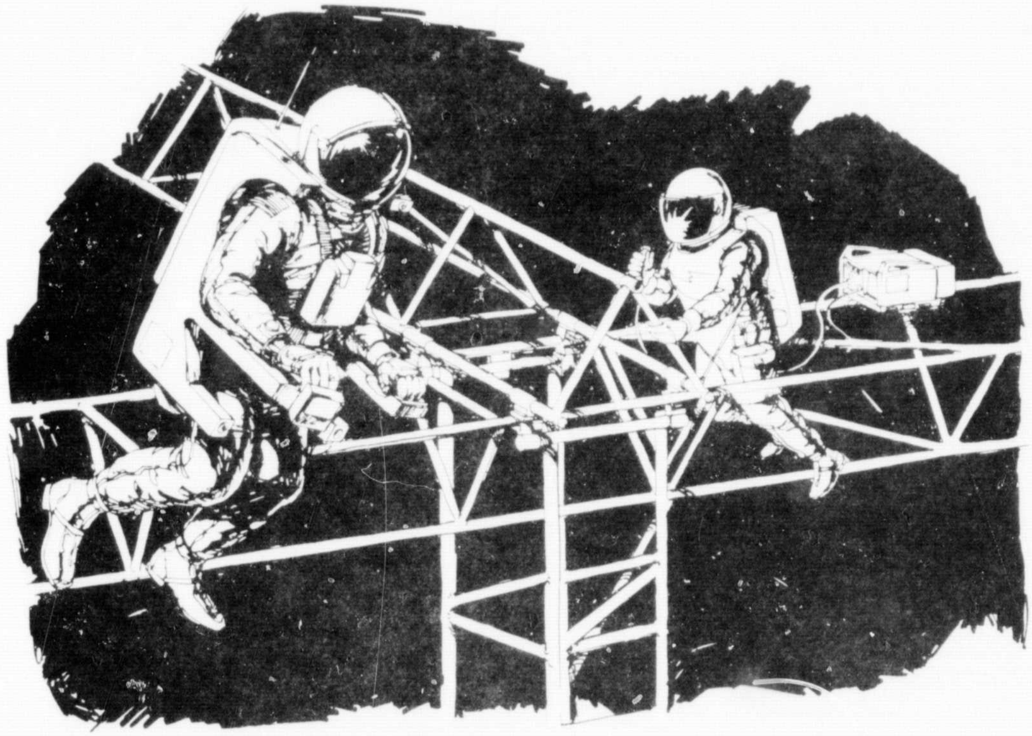

Figure 5. Structure Fabrication and Assembly in Space

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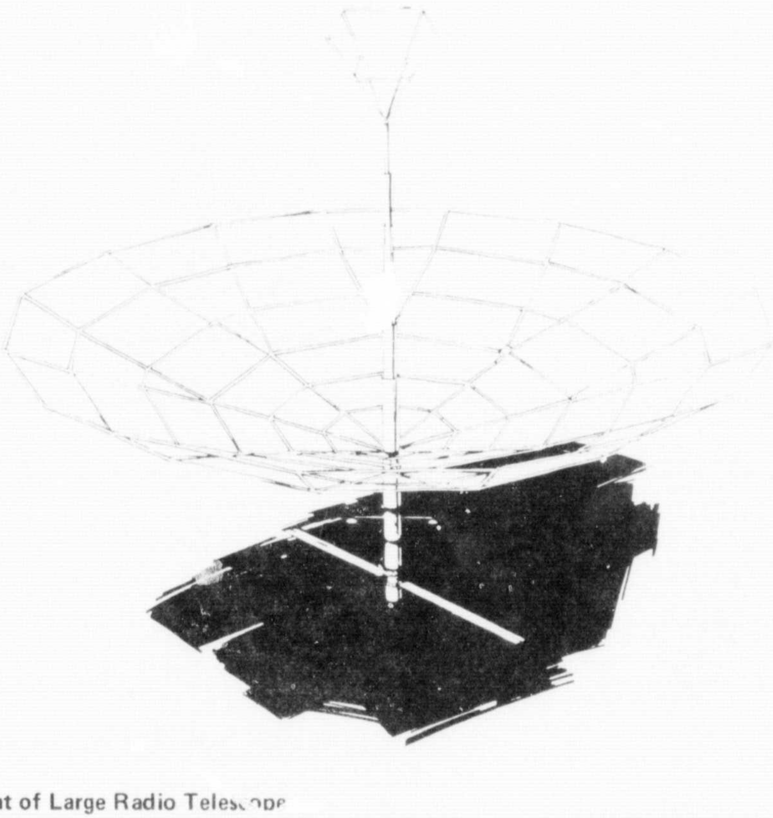

Figure 6. Deployment of Large Radio Telescope

Section 3

CONFIGURATION DEVELOPMENT

In order to provide growth capability yet remain within the payload length and weight constraints of the Shuttle transportation system, the final MOSC configuration will require some degree of modularization. Although many alternative configurations could be pursued, it was found advantageous in previous space station studies to group the functional requirements in terms of logistics requirements, subsystem requirements, payload requirements, and habitability requirements. Each of these requirements could be met either by packaging the associated systems and subsystems into separate modules or into combinations. In general, it is preferable to leave the habitability and subsystem support equipment in orbit, whereas the experiments and logistics items must of necessity be transported from the ground to orbit. Six alternative options were analyzed. These alternatives represented varying degrees of integration, as defined in Figure 7, and are shown pictorially with two to four modules being considered. The various options were compared, and for the reasons indicated on the figure, Option F was recommended as the baseline system.

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HM HABITILITY MODULE
LM LOGISTICS MODULE
PM PAYLOAD MODULE
SM SUBSYSTEM MODULE

OPTIONS		POSSIBLE – 4 MAN INTEGRATION VARIATIONS	GROUND INTEGRATION (COSTS)	MAX. MOSC MODULE LENGTH	LOGISTICS RESUPPLY FLEXIBILITY	EMERGENCY RETREAT	GROWTH BUILDUP
A	ALL MODULARIZED	LM SM HM PM (2)	VERY GOOD	MIN SATIS	EXC	EXC	EXC
B	INTEGRATED SUPPORT	HM/SM LM/PM	GOOD	SATIS	SATIS	POOR	GOOD
C	INTEGRATION FACILITY	LM/SM/HM PM	POOR	TOO LONG	POOR	POOR	POOR
D	SEPARATE SM	LM/HM/PM SM	POOR	TOO LONG	POOR	SATIS	POOR
E	MIXED FCTN INTEGRATION	HM/PM SM/LM	POOR	SATIS	POOR	GOOD	POOR
F	INTEGRATION ORBITAL ELEM	LM SM/HM PM	VERY GOOD	SATIS	EXC	EXC(1)	GOOD

RECOMMENDATIONS:

OPTION F PREFERRED

(1) PROVIDING INTERNAL BULKHEADS ARE ADDED
(2) PRESSURIZED OR UNPRESSURIZED

Figure 7. Configuration Options

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The four-man baseline configuration that resulted from the MOSC analysis is shown in Figure 8, and the key mission/vehicle design parameters are summarized in Table 5. The core vehicle consists of a subsystem module and a habitability module. It is proposed that the core vehicle be delivered in one Shuttle launch and normally left on orbital station for the life of the facility (5 years). The logistics modules and the payload modules would be launched on supplementary Shuttle flights as required, although it is proposed that nominally they be delivered and replaced at 90-day intervals.

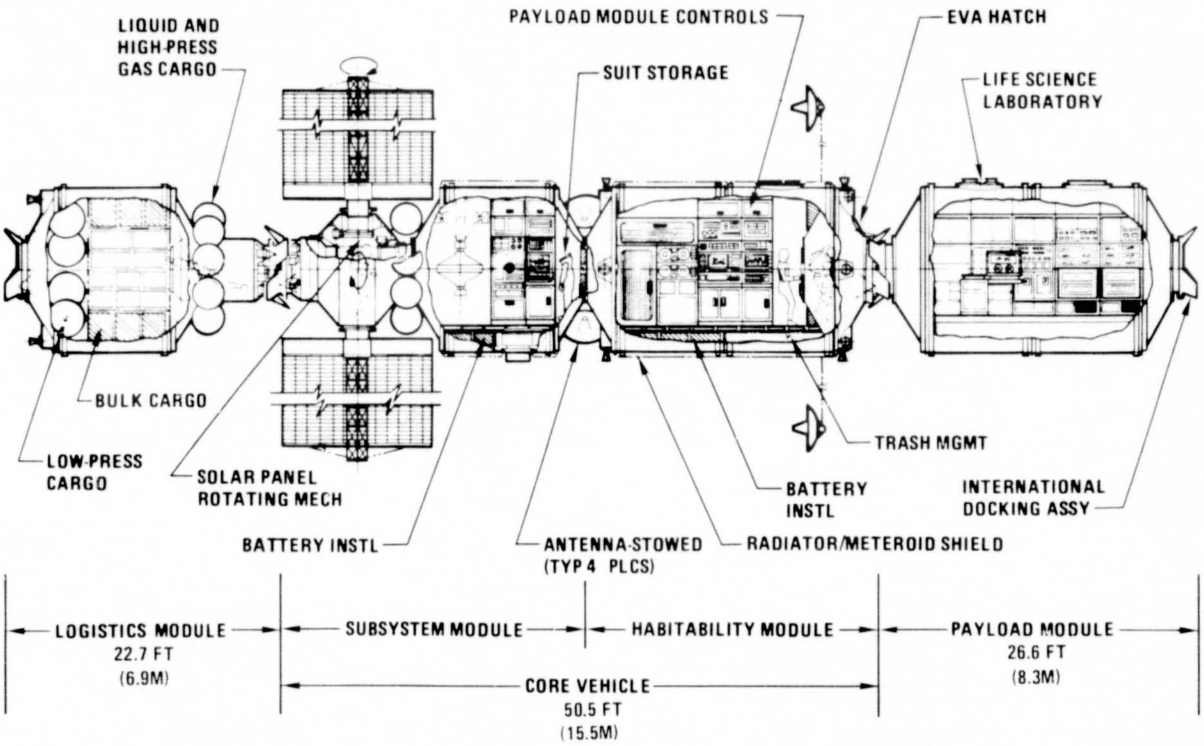


Figure 8. Baseline 4-Man MOSC

Table 5
MISSION/VEHICLE PARAMETERS

- Vehicle orbital life – 5 years
- Crew exchange period – 90 days
- Resupply period – 90 days
- Number of crew – 4
- Number of manned modules – 3 basic plus payload modules
- Number of unmanned pallets – 1 or more
- Orbital altitude – 200 nmi nominal (100- to 300-nmi range)
- Orbital inclination – 0° to 90° (one facility in 28.5 orbit and one facility in polar orbit)
- Vehicle orientation – all axes (universal solar array pointing)
- Launch weight – 65,000 pounds (maximum)
- Planned landing weight – 32,000 pounds

One of the key study ground rules was to use available hardware and technology (Orbiter, Spacelab, Skylab) insofar as practical in order to develop the most cost-effective total system. For this reason, the cylindrical pressure shell sections of the current European Spacelab were investigated and determined to represent feasible basic building blocks for the pressurized volumes, because these sections were designed specifically for use with the Shuttle transportation system. Previous studies have suggested that 200 cu ft/man is an acceptable lower limit of free volume for habitable vehicles. Accordingly, at least 800 cu ft of free volume would be required in a four-man habitability module. Predicated upon an equipment packing density of 60% and the requirement for 800 cu ft of free volume, the volume of the four-man habitability module should be at least 2,000 cu ft. By utilizing two cylindrical sections as developed in the current European Spacelab program, a habitability module volume of 2,450 cu ft can be obtained. This was selected as the size of the habitability module for the core vehicle. The size of the subsystem module was then established by utilizing the remaining available capacity of the Shuttle payload bay.

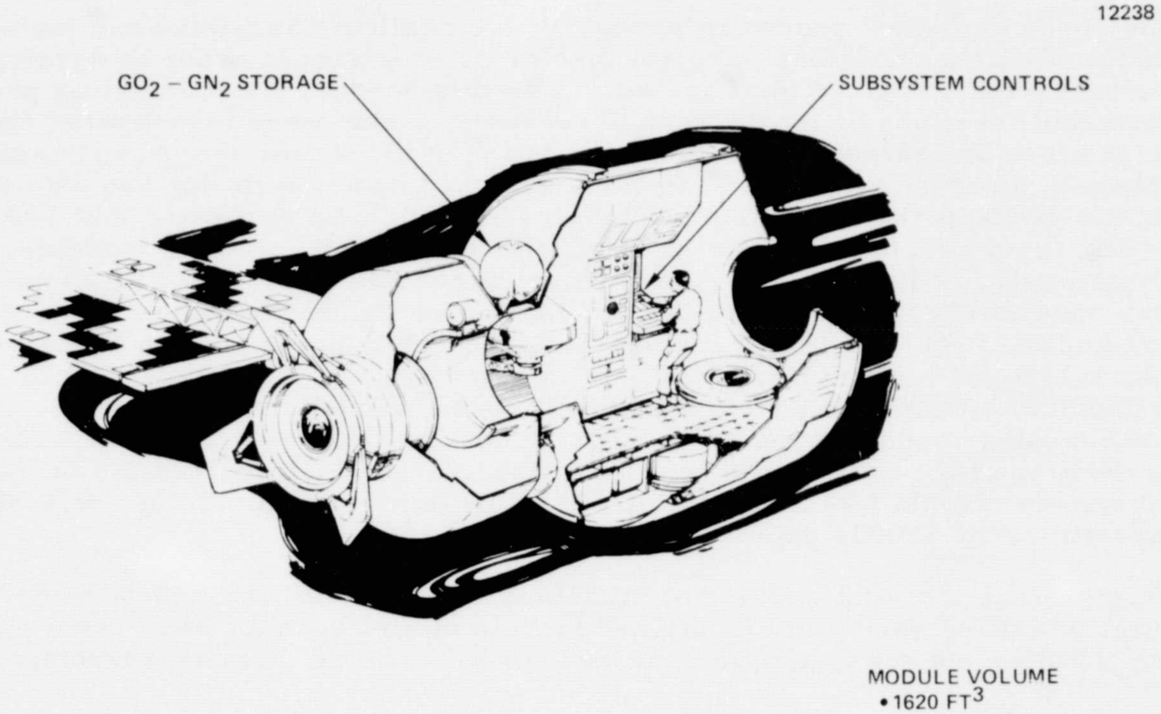
To minimize the total number of module configurations, the logistics module outer pressure shell and the payload module outer pressure shell were patterned after the subsystem module and the habitability module, respectively.

Initial studies indicated that adequate thermal control for the baseline facility can be provided by having the radiator/meteoroid shields mounted on the external portions of the habitability and subsystems modules only.

Cutaway views are shown of each of the four basic modules that together comprise the baseline configuration (Figures 9 through 15).

Several payload modules could be docked simultaneously in tandem to the core vehicle to provide expanded research facilities; the stabilization and control system of the baseline configuration has been sized to accommodate this possibility (Figure 16).

A summary of the principal subsystems selected for the baseline configuration and the programs in which they have been or will be developed is indicated in Table 6. The selection of the power system was one of the more important configuration determinants. Candidate concepts for power systems originally included fuel cells, rigid and rollout solar arrays, radioisotope thermoelectric generators (RTG's), and Brayton-cycle power conversion systems. Analysis of potential payload power requirements suggested that 8 kW of power should be available for the payloads, and preliminary design studies suggested that approximately 4 kW would be required for the various onboard subsystems. Thus, a total of 12 kW should be provided at the bus. As a result of the excessive reactant weight required for missions exceeding 7 days, fuel-cell technology was eliminated. RTG's were also eliminated due to the low output (150 W) of existing units, as were rigid solar arrays, the latter due to excessive weight and the assumption that the development of rollout/foldout arrays stemming from the Solar Electric Propulsion Stage (SEPS) program will continue. Remaining candidates were therefore rollout solar array/battery systems and Brayton systems fueled by plutonium-238 (Pu-238) or curium-244 (Cm-244).



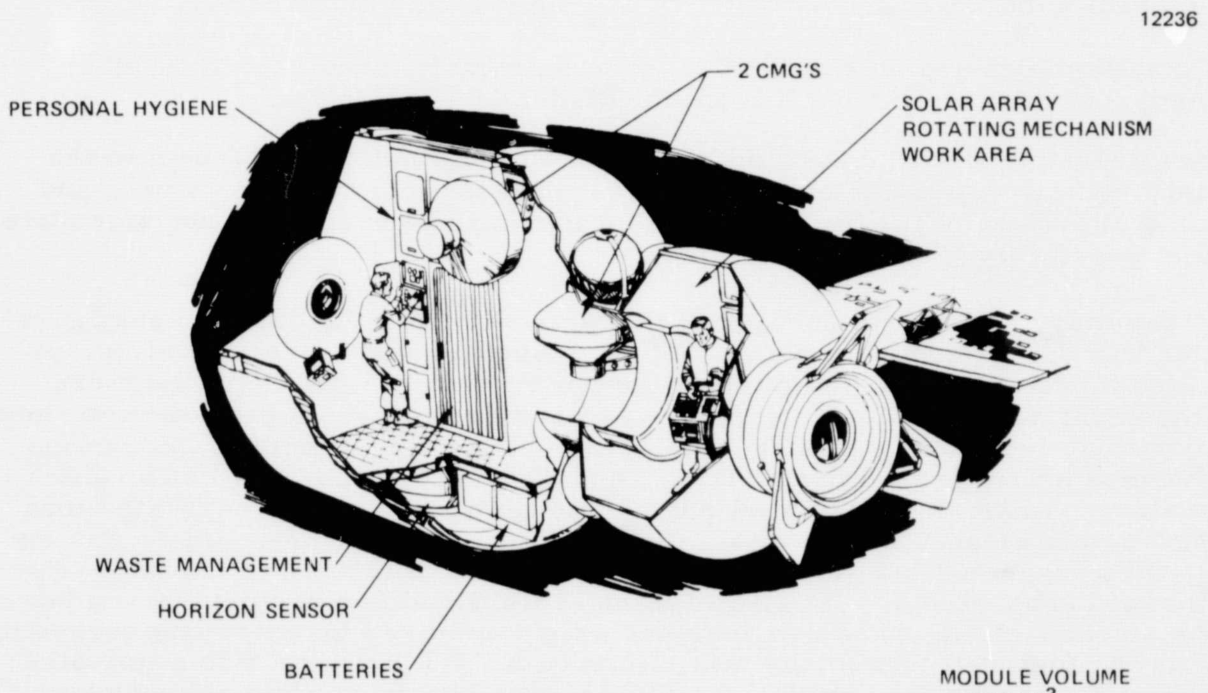
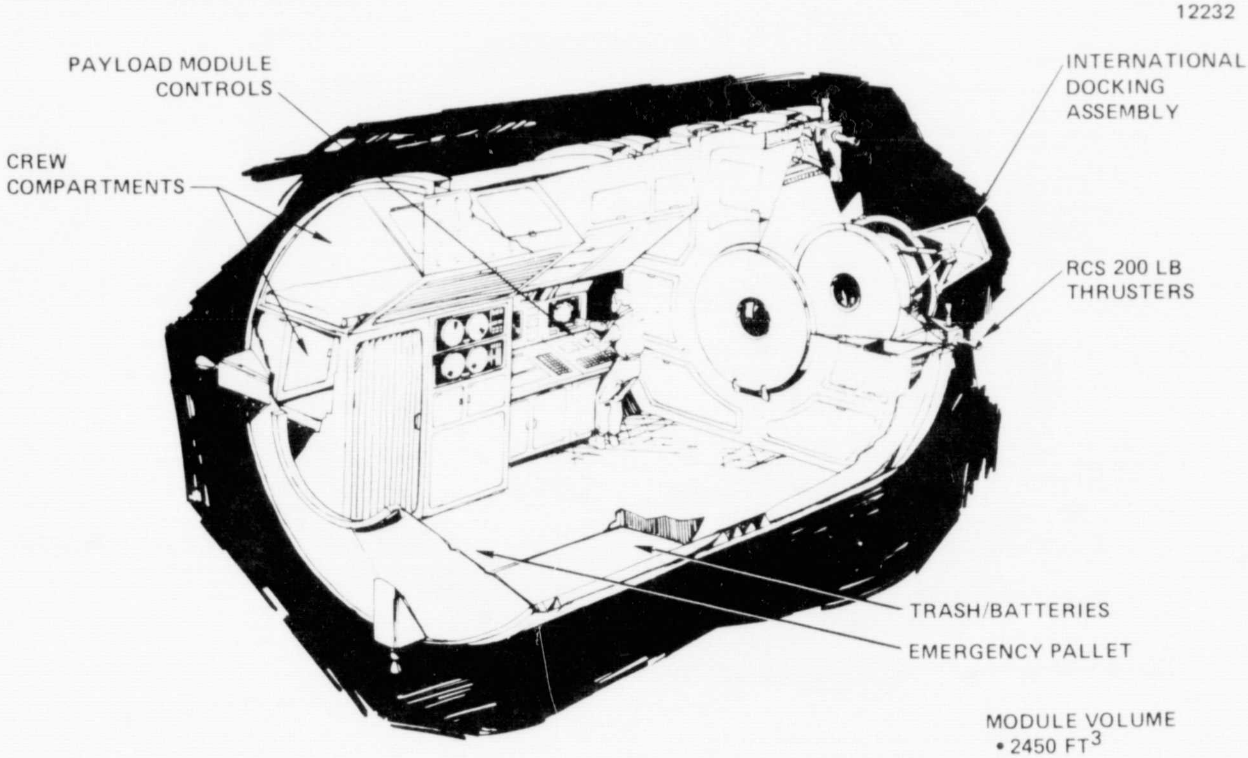


Figure 9. Baseline 4-Man MOSC – Subsystem Module



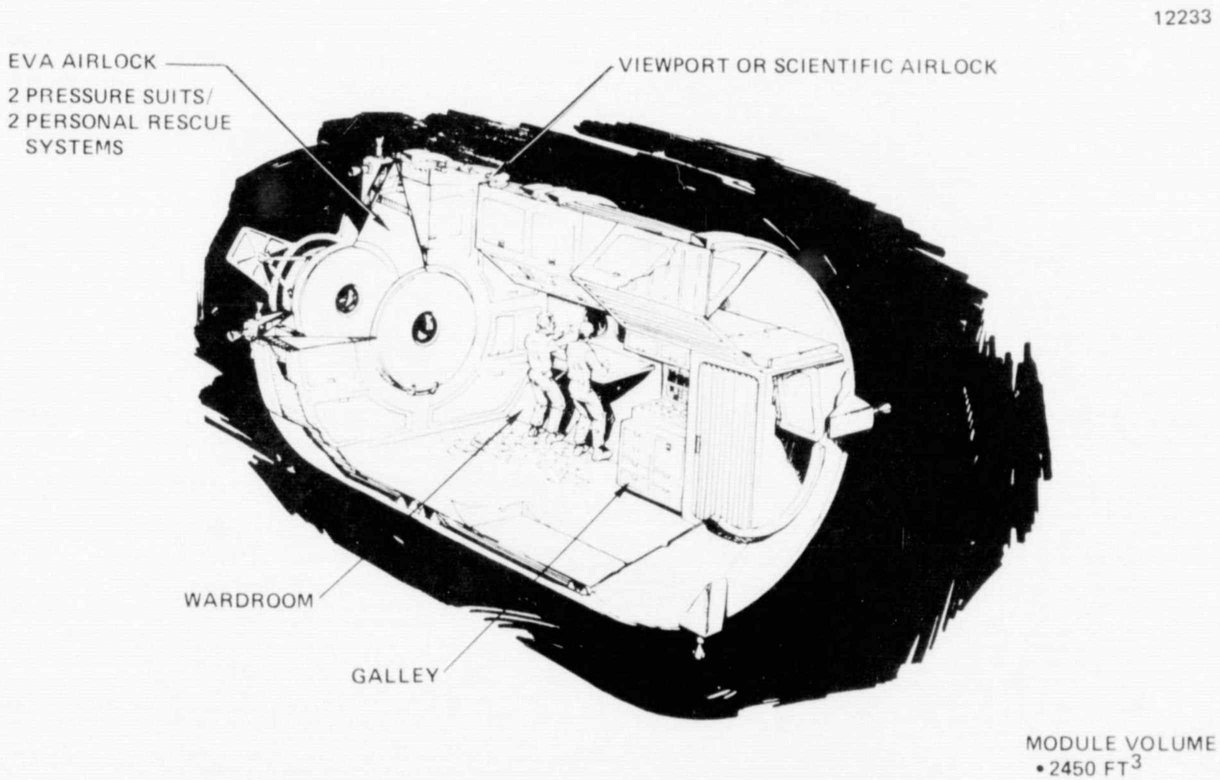


Figure 10. Baseline 4-Man MOSC – Habitability Module

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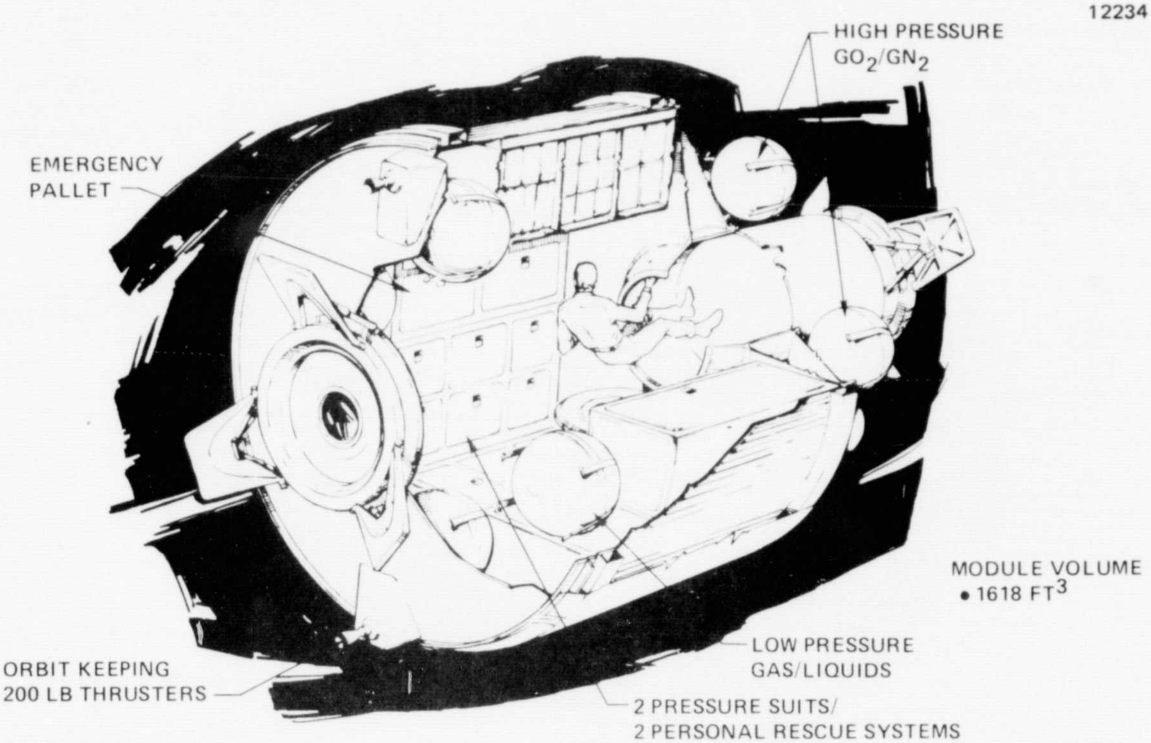

Figure 11. Baseline 4-Man MOSC – Logistics Module

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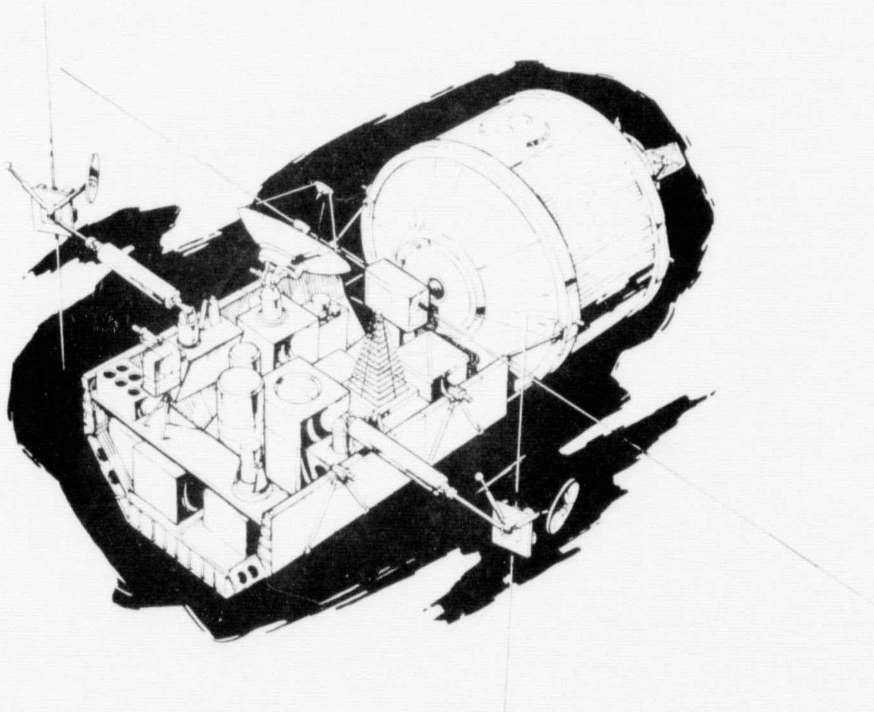

Figure 12. Baseline 4-Man MOSC – Payload Module and Pallet

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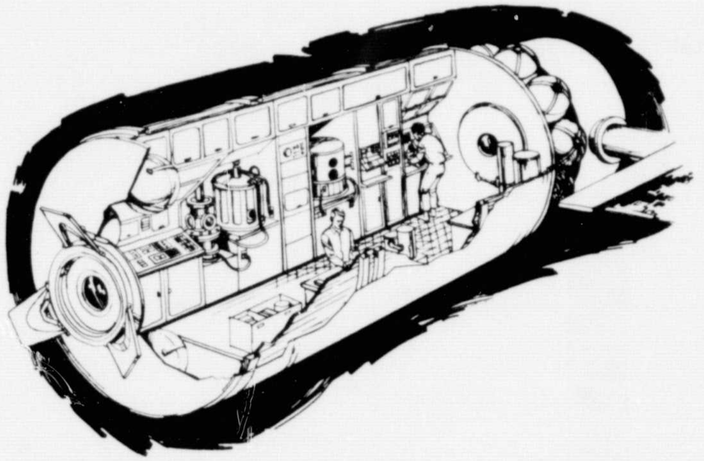

MODULE VOLUME
• 3500 FT^3

Figure 13. Space Processing Payload Module

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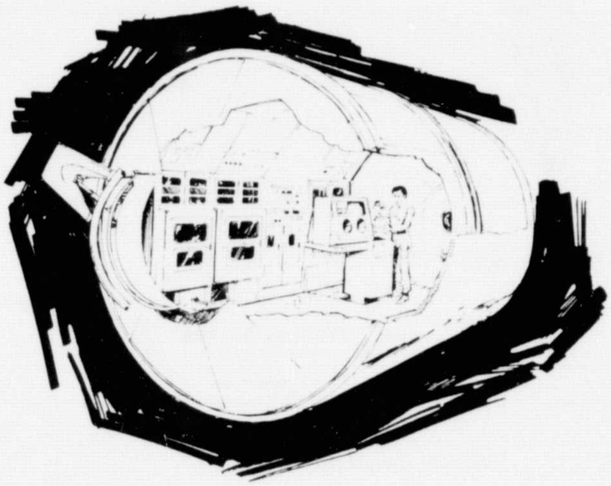

Figure 14. Life Sciences Payload Module

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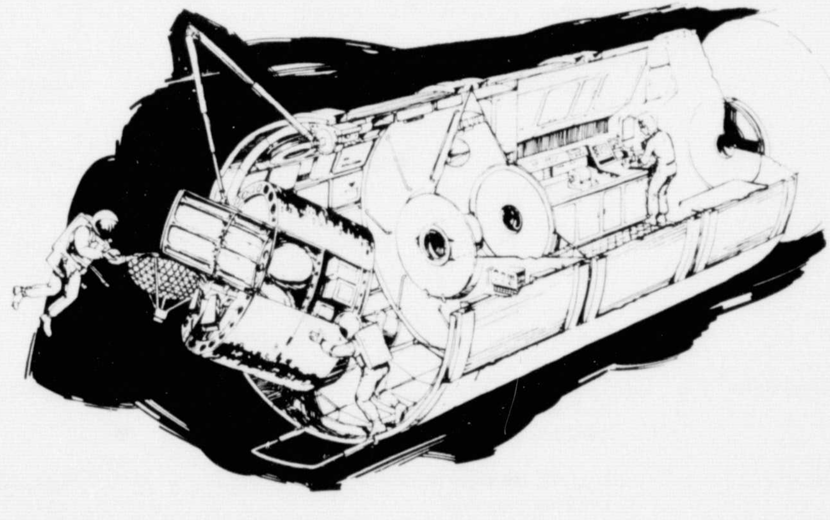

Figure 15. Satellite Repair Facility

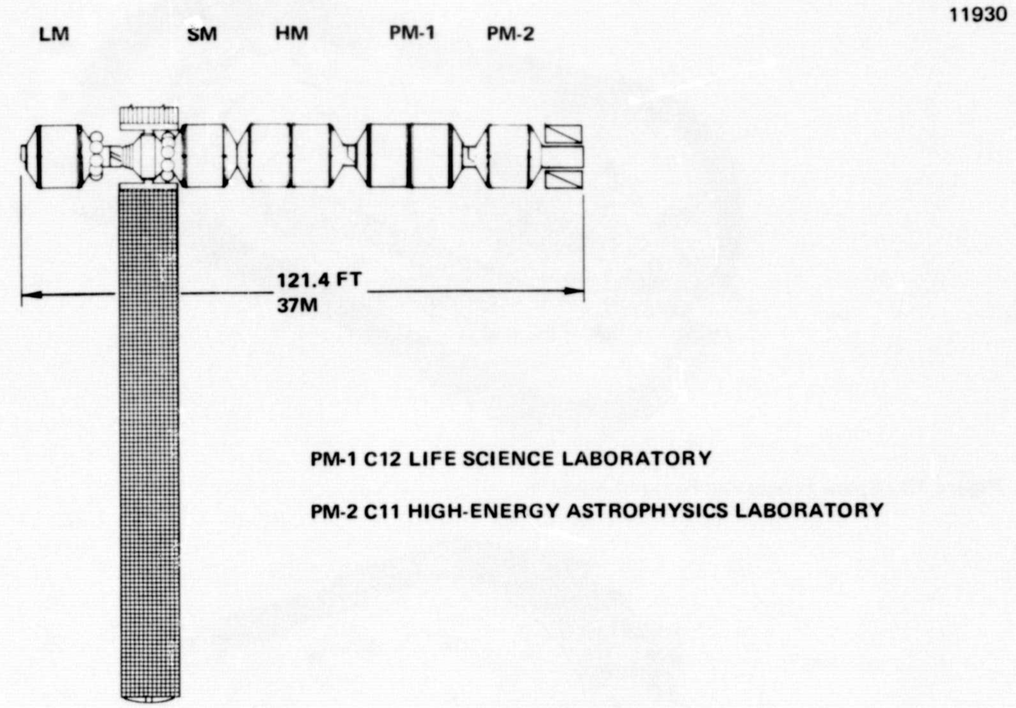

Figure 16. Typical MOSC – Payload Orbital Configuration

Table 6
SUBSYSTEM SUMMARY

Subsystem*	Selection	Source
• Crew accommodations		
– Waste management	Centrifugal separator	Orbiter
– Crew equipment	Restraints, personnel gear, et al.	Orbiter/Skylab
• Environmental control/life support	1 Atm Closed H_2O (vapor compression) Open O_2 (LiOH for CO_2 removal)	Orbiter/Spacelab
• Electric power	25-kW solar arrays (12 kW at bus) 36-kWh batteries (12)	SEPS Orbiter
• Data management		
– Experiment	Distributed (1 MBPS serial data, 40-K word memory)	Orbiter/Spacelab
– Vehicle	Centralized	Orbiter
• Communications	S-Band Ku Band	Orbiter Orbiter
• Stability/control	CMG's (3) (18,000 ft lb-sec each) Sensors (edge tracker, gimbaled star tracker, solar)	Skylab (improved) Orbiter/Skylab
• Reaction control/propulsion	Cold Gas – GN_2 60-k lb-sec total impulse 14 thrusters at 200 lb each	Skylab
• Structural/mechanical	Modular (primary structure) Docking assembly	Spacelab ASTP

*APPROXIMATELY 75% OF MOSC COMPONENTS IDENTIFIED AS AVAILABLE HARDWARE OR TECHNOLOGY

The use of rollout/foldout solar arrays results in the lowest-weight system for a given power output. This is due to the thickness of lithium shielding for Brayton systems required to maintain a reasonable crew radiation dose rate. Furthermore, the Brayton cycle radiator area was of concern because it would have competed with the ECLS system for available station external surface area. Inasmuch as the thermal control system, in rejecting 12 kW, already uses the surface area of two modules, there would be little remaining surface for the Brayton system's use. The close match between the SEPS array characteristics, including the minimal shadowing effect of the narrow configuration and the power budget required to deliver 12 kW at the power bus, was also a factor in its selection.

The location of the flexible foldout solar arrays posed a particular problem. These arrays are approximately 104 feet (31.6 m) long and 13.1 feet (4 m) wide. They rotate about their own longitudinal axes as well as around the central axis of the facility. This provides continuous solar orientation of the arrays regardless of the orientation of the MOSC configuration. To establish the location of the solar arrays, the Shuttle interface and docking requirements, the potential structural/mechanical problems of leakage, the ECLS problems of shielding radiator surfaces, the communications equipment problems due to the solar arrays shadowing antennas or otherwise causing transmission signal loss, the propulsion problems of minimizing impingement, the impacts on crew safety, weight factors, and logistics factors were considered. The results of these analyses established the optimal location to be on the subsystems module at the end furthest removed from the habitability module.

The location of the principal safety items and subsystems are summarized in Figures 17 and 18.

The compartmentalization approach to the MOSC configuration provides inherent safety because any one compartment can be depressurized if necessary without affecting the remaining compartments. Each compartment has dual egress capability, either directly into another compartment, or to space by means of pressure suits and personnel rescue systems located in the end compartments. An EVA hatch is also located in the end dome of the habitability module. The logistics module and the habitability module contain emergency stores for four men for 150 hours.

Each compartment is supplied with atmospheric inputs; power, logistics, communication, and signal conditioning outlets; and fire detection and fire suppression equipment. For safety, all high-pressure bottles are located external to the pressure shells, with the valving on these bottles oriented away from the vehicle.

The dimensional relationships of the core vehicle and the logistics and payload modules to the Orbiter cargo bay are shown in Figure 19. Sufficient clearance is provided to permit longitudinal adjustment of the modules to mate with Orbiter attach points. Inasmuch as the habitability module and the subsystems module will be launched together and will remain in orbit, there is no need for a docking assembly between these two units, so they are bolted together on the ground. Each of these modules contains hatches at the interface and each could be sealed off from the other so that, if necessary, they could be manually separated in space and returned to Earth individually.

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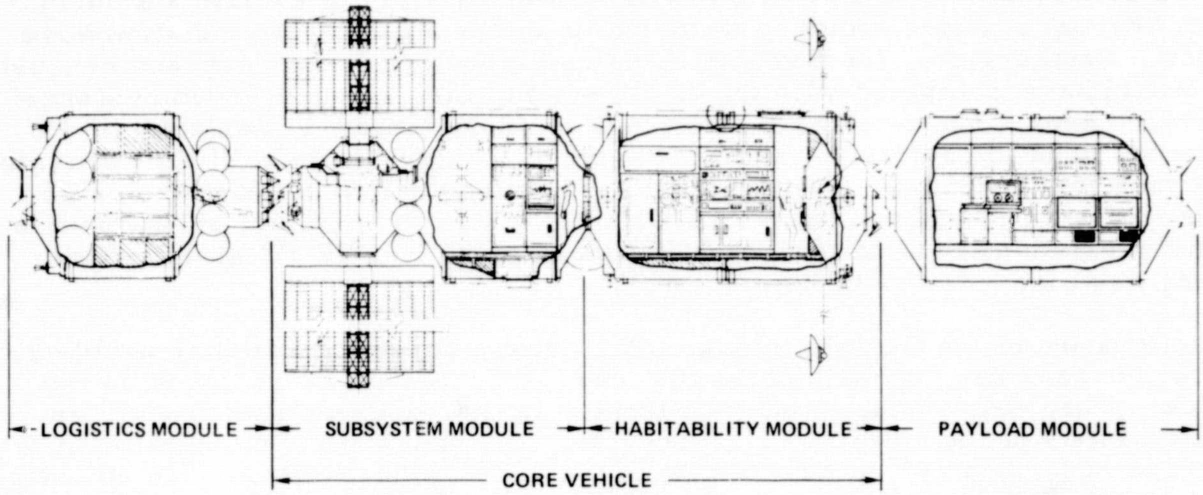


SAFETY EQUIPMENT

LOGISTICS MODULE	SUBSYSTEM MODULE	HABITABILITY MODULE	PAYLOAD MODULE
AIRLOCK, 2 PRESS. SUITS, BACKPACKS, 2 PERS RESCUE SYS, EMERG PALLET – 4 MEN 150 HR, FIRE DETEC, FIRE SUPPRESS.	FIRE DETECTION, FIRE SUPPRESSION	AIRLOCK-EVA HATCH, 2 PRESS. SUITS, 2 BACK-PACKS, 2 PERS RESCUE SYS, EMERG PALLET – 4 MEN 150 HR, FIRE DETEC, FIRE SUPPRESS.	FIRE DETECTION, FIRE SUPPRESSION

Figure 17. Baseline 4-Man MOSC Major Subsystems and Safety Equipment Summary/Locations

11928

	LOGISTICS MODULE	SUBSYSTEM MODULE	HABITABILITY MODULE	PAYLOAD MODULE
ECLS	H_2O/GAS, STOR DUMP/REL	THERM CONT, ATMOS COND, H_2O RECOV, H_2O/GAS STOR, AVION COOL, DUMP/REL VAL	ATMOS COOL, H_2O DISP, DUMP/REL VAL. THERM CONT.	OUTLETS, ATMOS COOL, DUMP/REL VAL
POWER	LIGHTING OUTLETS	SOLAR ARRAYS, POWER CONT/REG, DC CONV, BATT, INVERT - 400 Hz	DC CONV, BATT, INVERT - 60 Hz	LIGHT, OUTLETS, REMOTE POWER CONT
DATA MANAGEMENT SUBSYSTEMS	REMOTE ACQUIS/CONTR, SIG COND	SIG COND, MULTIPLEX, RECORD, COND DISPLAY, TV CAUTION/WARN	TV CAM, SENSORS, REMOTE C/D, SIG COND	SIG COND
DATA MANAGEMENT PAYLOAD SUPPORT			MASS MEM, PROC, RECORD TIMING, C/D, CRT	PROC, CONVER, CRT X-Y PLOT
COMMUNICATIONS	REMOTE AUDIO TERM	S-BAND, FM, PM, AUDIO CONT ANT	KU-BAND, ANT, FM TRANS, SIG PROC	REMOTE AUDIO TERM
STABILITY/CONTROL		CMG'S, ATTITUDE REF, GYROS -3 CMGS, HORIZON SENSOR, SWITCHING LOGIC		
PROPULSION / REACTION CONTROL	GN_2 STOR, VALVING, THRUSTERS, TRANS	GN_2 STOR, VALVING	THRUSTERS, VALVING	

Figure 18. Baseline 4-Man MOSC Major Subsystems

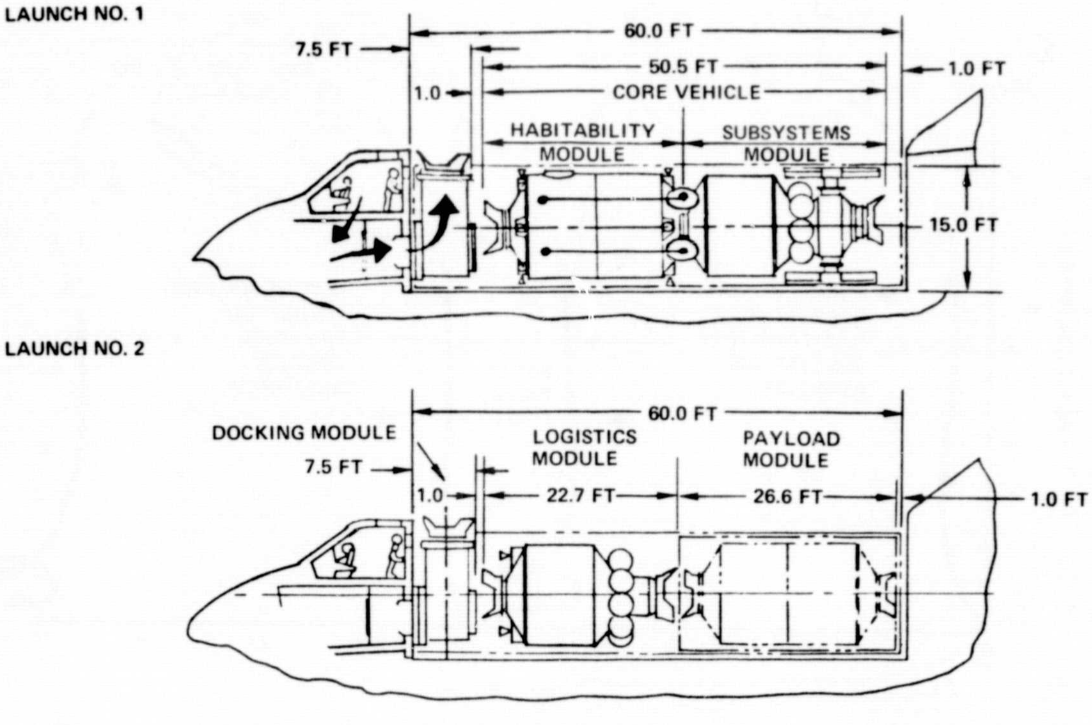


Figure 19. Baseline 4-Man MOSC Orbiter Cargo Bay Installation

The launch sequence would call for delivery of the core vehicle (habitability and subsystems modules) on the first launch (Figure 20). A nominal period of four days would be required to deliver the core vehicle, check out all systems while the vehicle was still attached to the Orbiter, deploy the core vehicle, and return to Earth.

Assuming a typical ground turnaround time of 7 days for the Shuttle transportation system, on the eleventh day the second launch of the Orbiter would deliver the logistics module and the payload module assembly. These modules would be docked to the core vehicle, the crew would be transferred and the system completely checked out, and the Orbiter would return to Earth on the fifteenth day, leaving the MOSC operational in orbit. Figures 21 and 22 illustrate one way in which the baseline facility might be deployed. The six steps shown are predicated upon the use of only one remote manipulator system. With two manipulator arms, other docking and assembly techniques are possible. Figure 23 illustrates one procedure for exchanging logistics modules (or payload modules) on subsequent 90-day resupply flights.

The initial missions for the baseline four-man facility will be in a 28.5° orbit and will consist of multidiscipline orbital research programs. The initial facility will have flexible accommodations/subsystems to support a full span of scientific and technological projects. Approximately 2 years after the initial system is operational, a second facility can be located in polar orbit. The basic core facility can grow easily into an 8- to 12-man facility by including additional units as the demand for orbital activities grows. The

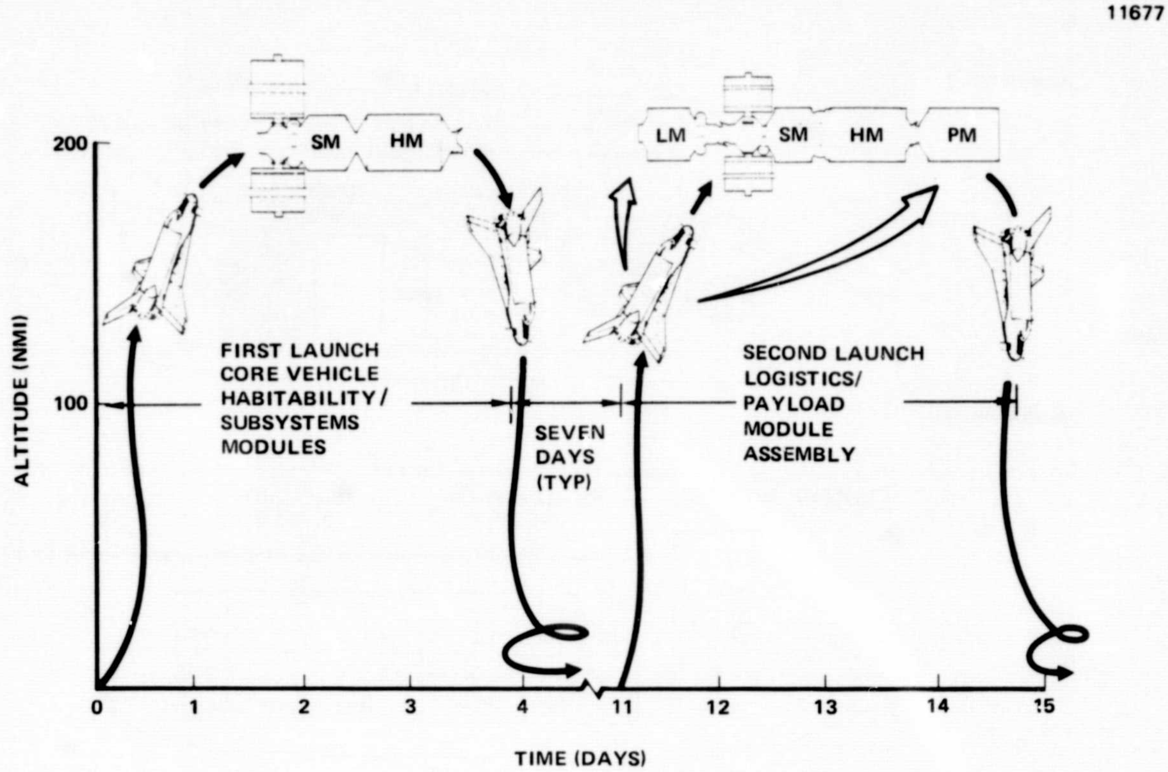


Figure 20. Baseline 4-Man MOSC Mission Profile – Vehicle Assembly

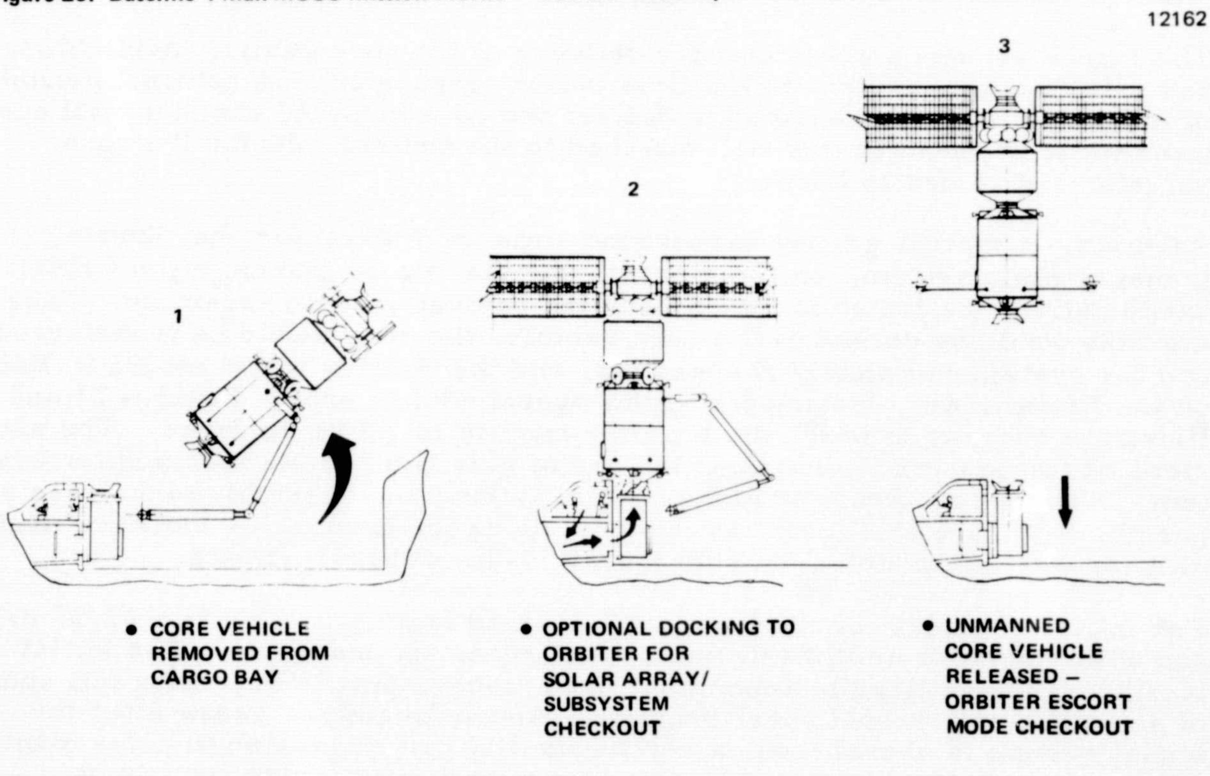


Figure 21. Baseline 4-Man MOSC Initial Orbital Sequence, First Launch – Core Vehicle Deployment

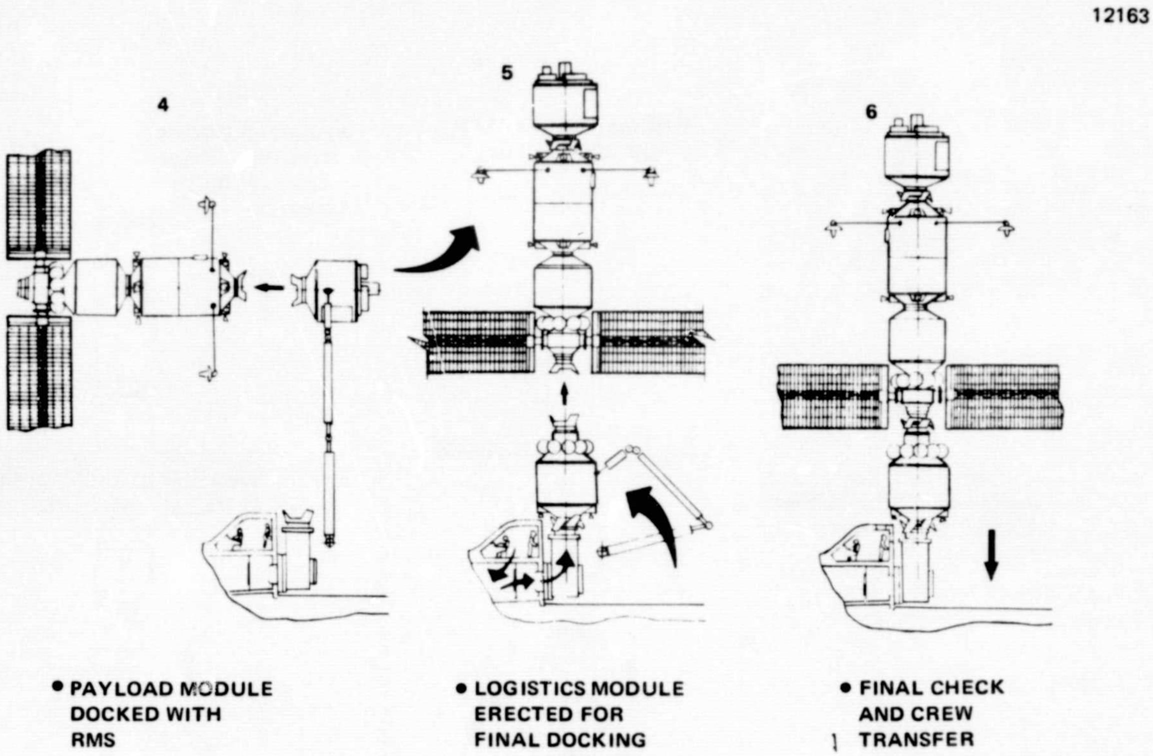


Figure 22. Baseline 4-Man MOSC Initial Orbital Sequence, Second Launch — Logistics/Payload Module

28.5° and polar facilities will be supported by Orbiter launches from KSC and from VAFB. In the 1990's such activities as commercial applications of space manufacturing may be anticipated.

The basic concept provides a number of growth options (Figure 24) leading to geosynchronous facilities and expanded operations in low Earth orbit. The basic design can provide a long-duration manned facility for the support of satellite servicing and the assembly of large space structures. These missions may involve space structure assembly projects in which large assemblies such as radio telescopes are assembled manually in low Earth orbit and then moved to the desired operational orbit by unmanned Tugs. The maintenance/checkout and crew-supported functions necessary to achieve these capabilities are inherent in the baseline concept. Interface capabilities could be designed into the initial modules with a minimum impact on system weight and cost. By using the manned orbital facility in low Earth orbit to perform these types of support tasks, Shuttle launches would be reduced and the on-orbit stay time of serviced equipment would be increased.

As the facility grows to accommodate larger crew sizes and multiple payloads, end-docking may no longer be the most effective procedure. One option is to reconfigure the habitability module (HM) and incorporate three side-docking ports. This provides additional docking ports for long-term experiments, short-term experiments, habitability, and/or logistics modules. This concept restricts the utility of the initial HM, since it is used to provide

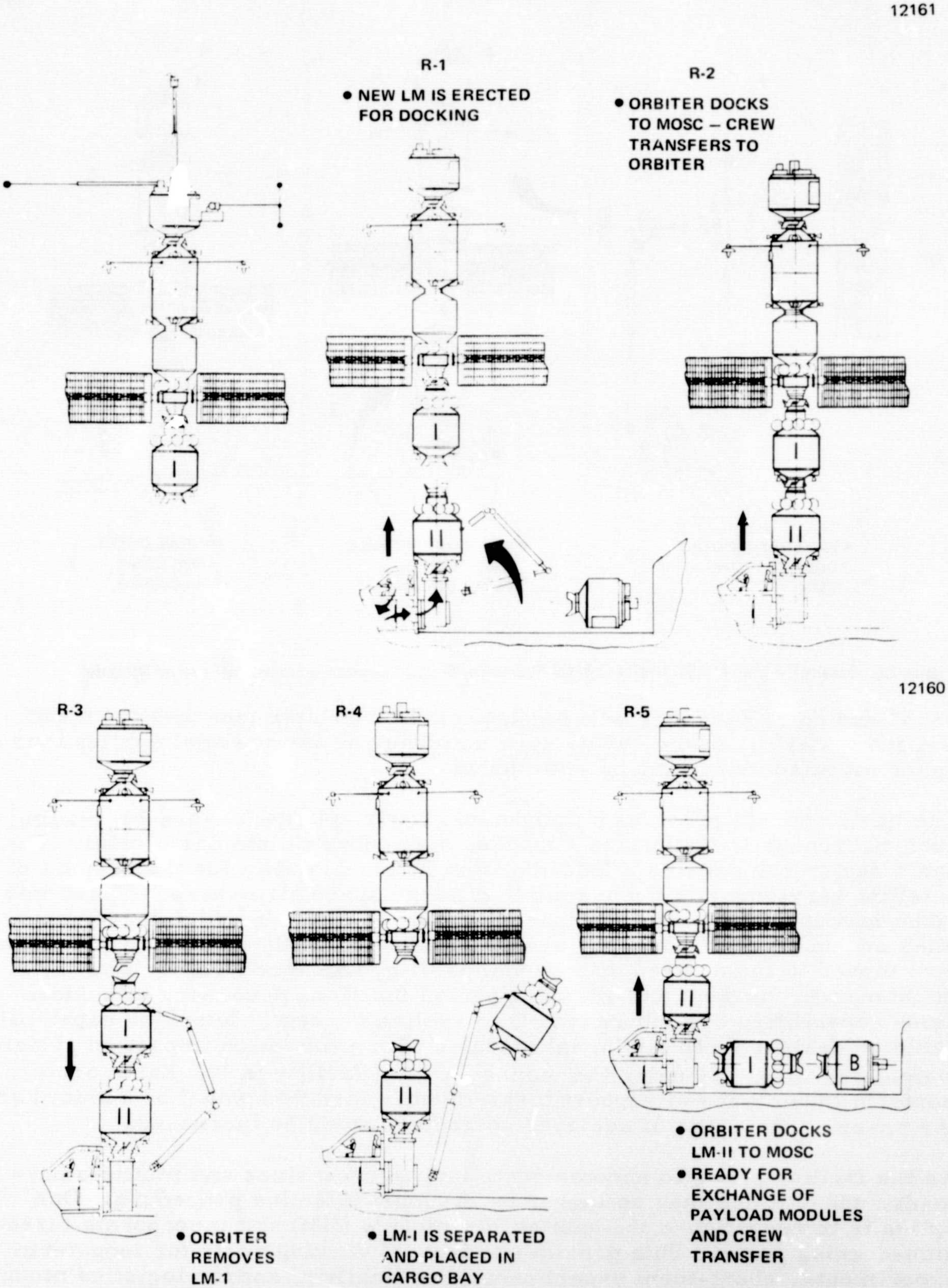


Figure 23. Baseline 4-Man MOSC 90-Day Resupply – Logistics Module

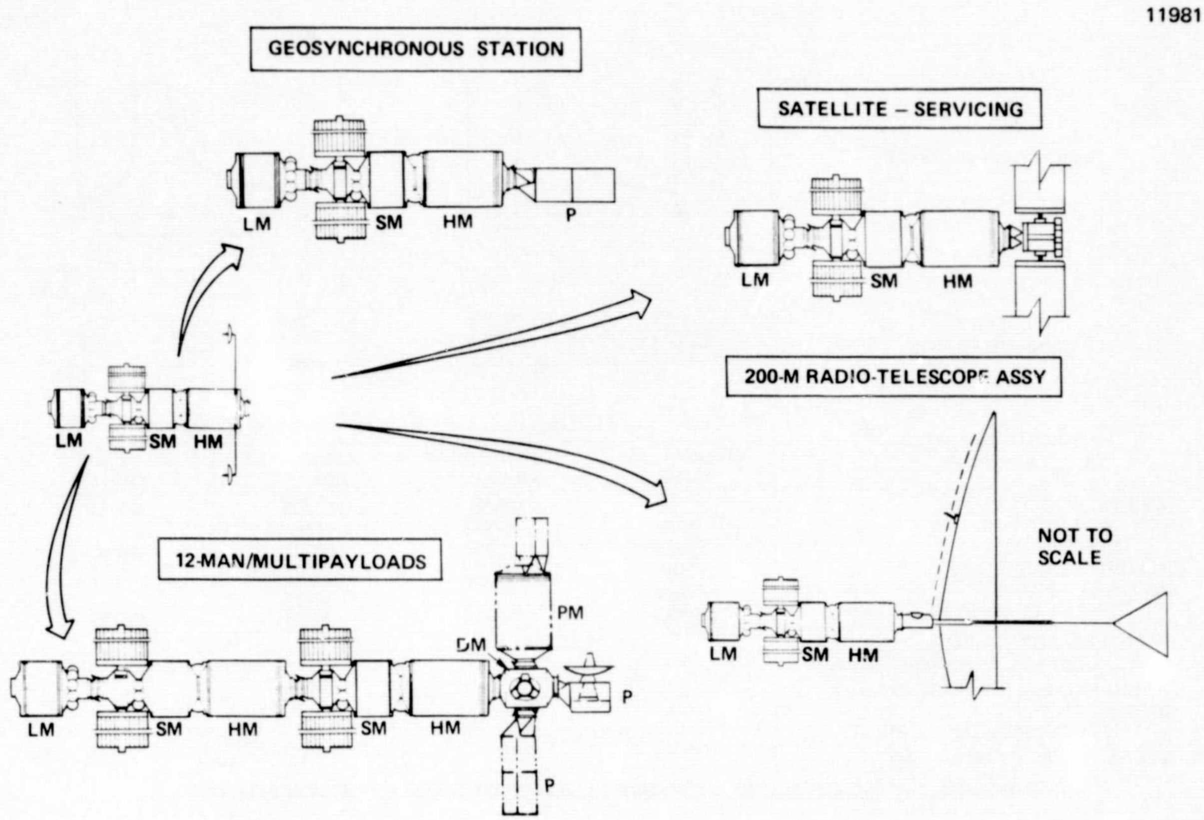


Figure 24. Future Mission Aspects – Growth Options

additional docking capabilities. Another solution would be the introduction of a dedicated docking module (DM) to facilitate the accommodation of radially docked modules for additional crew, large experiments, or additional subsystems.

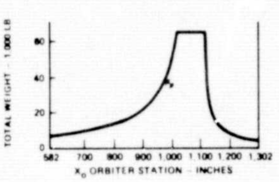
The docking module could also utilize some of the structural elements being developed for Spacelab. It could incorporate two end ports and three side ports. Previous MDAC modular space station studies(3) indicated three side ports were optimum, and the MOSC Study to date has supported this finding. A more detailed evaluation of the docking port/crew/facility interface requirements will determine the exact size and number necessary to perform multipayload functions.

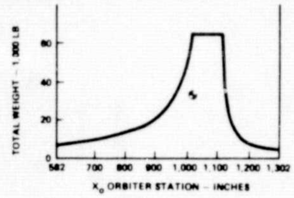
The growth versions shown in Figure 24 are but a few of those that can be visualized.

The mass properties of the baseline vehicle are presented in Figure 25. The four primary modules are designed so that the center of gravity (CG) of the core vehicle and the logistics/payload module combination are well within the acceptable launch-and-landing CG envelope of the Orbiter. Although the

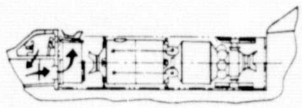
(3) NASA Phase B Space Station Definition, Contract NAS8-25140, McDonnell Douglas Astronautics Company, Huntington Beach, California. 1970-1972. Executive Summary, MDC G2587, December 1971.

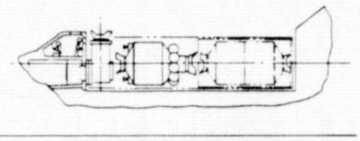
CENTER OF GRAVITY





LAUNCH CONFIGURATION





MASS PROPERTIES SUMMARY	FIRST LAUNCH		SECOND LAUNCH	
	SUBSYSTEM MODULE	HABITABILITY MODULE	LOGISTICS MODULE	PAYLOAD MODULE
SUBSYSTEM TOTAL	15393	12652	12303	6044
CONTINGENCY	1785	1423	1764	604
INERT MASS	(17178)	(14075)	(14067)	(6648)
RESIDUALS/RESERVES	144	816	999	227
INFLIGHT LOSSES	268	–	1458	–
TOTAL MOSC MASS (LBM)	(17590)	(14891)	(16524)	(6875)
TRANSFER/DOCKING MODULE/CREW	2200		3700	
TOTAL LAUNCH MASS (LBM)	(34681)*		(27099)	
INFLIGHT LOSSES & JETTISONABLE CONSUMABLES	-268		-1458	
LANDING MASS (LBM)	(34413)*		(32000)	
DISCRETIONARY MASS (LBM)			6359	

*CAN TRANSFER MASS TO SECOND LAUNCH IF 32,000 LB LIMIT CAN NOT BE EXCEEDED

Figure 25. Baseline 4-Man MOSC Mass Summary, 90-Day Logistics Cycle

launch-and-landing weight for the core vehicle exceeds 32,000 pounds, equipment and stores can be off-loaded or transferred to the second launch if it is deemed necessary to restrict the core vehicle weight to the Orbiter landing weight limit.

Section 4

PROGRAMMATIC FACTORS

A project schedule for the design and development of the manned orbital facilities described on the preceding pages is presented in Figure 26. This schedule reflects a nominal 5-year (60-month) development period typical of programs of a level of sophistication equivalent to that visualized for the facilities and concepts developed in the MOSC Study. The schedule shows the phasing of the major development activities and provides the basis for developing funding curves for the total program. For planning purposes, ATP for the Phase C/D design development activity is set at January 1, 1980, and the IOC for the orbital facility at 28.5° is set at December 31, 1984.

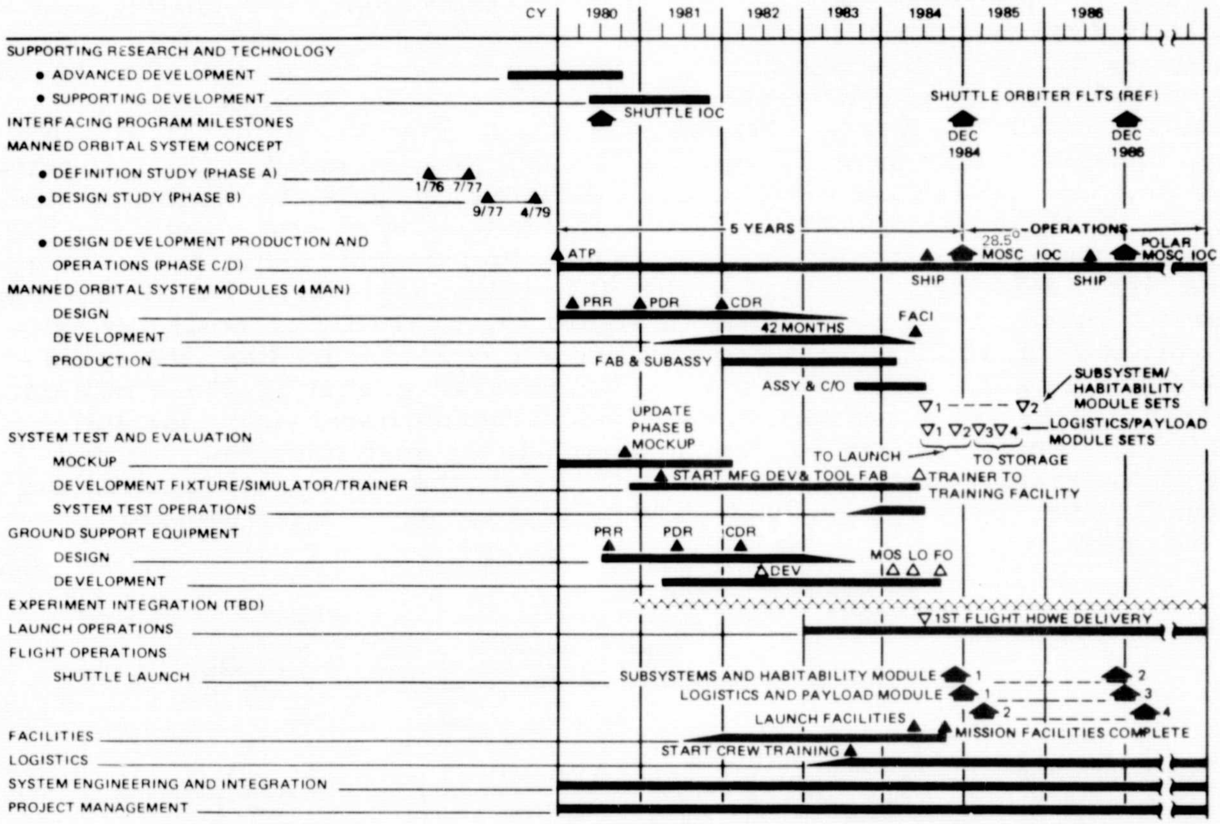


Figure 26. Baseline 4-Man MOSC Project Schedule

The symbols and abbreviations used on this figure are as follows:

(filled pentagon arrow)	Spacecraft operational launch	ER	Engineering release	MOS	Manned orbital system
▲	Milestone event	FAB	Fabrication	PDR	Preliminary design review
Δ	Shipment and delivery	FACI	First article configuration inspection	PRR	Preliminary requirements review
ATP	Authority to proceed				
CDR	Critical design review	FO	Flight operations	FRR	Flight readiness review
C/O	Checkout	LO	Launch operations	(wavy line)	To be determined (TBD)

In developing the cost estimates, the project schedule (Figure 26) and a work breakdown structure (WBS) provided the basic framework for the analysis. The WBS (described in Book 4) is a task-oriented family-tree hierarchy that contains five levels of work required to be accomplished in order to achieve the MOSC objectives. The program costs were predicated upon a no-frills, minimum-cost approach to development, requiring streamlined contractor management, maximum use wherever possible of existing hardware and/or technology, and tight control of program changes. The use of significant amounts of existing Spacelab and Orbiter hardware or technology decreased the development cost of the program elements considerably and resulted in a low development-to-production cost ratio. In cases where the actual costs or estimates of cost for production items were not available from their manufacturers, estimates were made by MDAC pricing personnel using standard MDAC cost-estimating ratios and other cost factors as appropriate.

The costing estimates for the design, development, test, and engineering; production; and operations phases of the MOSC program are summarized in Figure 27. Figure 28 summarizes the engineering design and development costs for the modules that make up the baseline facility, and Figure 29 summarizes the production cost for these units. These cost estimates are based upon a 5-year development schedule and a 5-year operations period, which includes a 2-year gap between the launch of facilities in a 28.5° orbit and those in a polar orbit. A total of 12 modules is included in the cost estimates. One habitability module, one subsystems module, two logistics modules, and two payload modules were assigned to a 28.5° orbit, and a similar set was assigned to the polar orbit. In addition, the cost estimates included one high-fidelity trainer/simulator ($84.5 million of the $111.1 million shown for the logistics cost). As shown in Figure 27, total DDT&E costs are estimated at $571.4 million, the production costs at $313.6 million, the operations costs at $299.6 million, and the total program cost at $1,184.6 million. These figures are based upon mid-1975 Government fiscal year constant dollars, no prime contractor fee, and exclude the sustaining Shuttle transportation system costs (including launch costs), the flight crew salaries and benefits, the cost of the payloads, and the cost for experiment/payload integration.

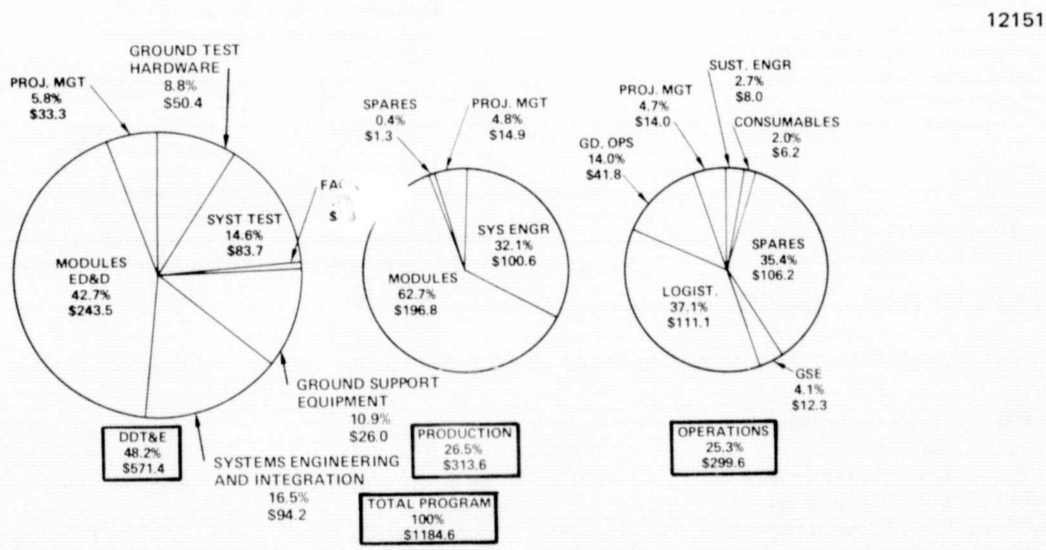


Figure 27. Total Program Cost for MOSC 4-Man 2-Orbit Facility (Millions of FY 75 Dollars)

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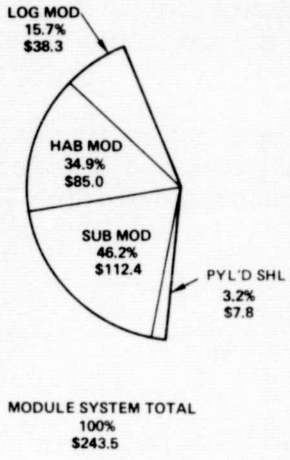

	MODULES			
	LOG	HAB	SUB	PAYL'D
STRUCTURE	7.3	6.3	9.5	3.3
ECLS	7.7	9.1	22.4	—
CREW ACCOM.	1.6	10.2	8.4	—
ELEC. PWR.	12.6	23.7	45.8	—
COMMUN.	.0	13.0	2.3	—
DATA MGT	—	7.5	4.0	—
STAB. AND CONTL.	—	—	2.6	—
PROPULSION	.6	.3	.2	—
ENVIRON. PRT.	3.0	2.9	2.6	2.6
INTEGR.	5.5	12.0	14.6	1.9
TOTAL	38.3	85.0	112.4	7.8

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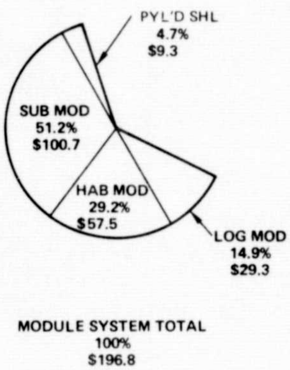
Figure 28. Detail of Engineering Design and Development Cost for Modules (Millions of FY 75 Dollars)



	MODULES			
	LOG	HAB	SUB	PAYL'D
STRUCTURE	9.2	4.2	5.2	6.5
ECLS	.7	10.6	14.7	—
CREW ACCOM.	.7	4.9	8.4	—
ELEC. PWR.	8.4	7.6	38.0	—
COMMUN.	.1	13.0	4.4	—
DATA MGT.	—	5.4	5.7	—
STAB. AND CONTL.	—	—	7.9	—
PROPULSION	5.0	2.1	.5	—
ENVIRON. PRT.	.7	.9	.6	1.4
INTEGR.	4.5	8.8	15.3	1.4
TOTAL	29.3	57.5	100.7	9.3

Figure 29. Detail of Production Cost for Modules (Millions of FY 75 Dollars)

The DDT&E costs shown for each module in Figure 28 are determined by prorating the DDT&E costs for each subsystem among the modules using that subsystem. Therefore the DDT&E cost shown for any module is not representative of the cost that would be incurred if that module were developed separately. All four of the modules must be developed as a part of the same program for the estimates to be valid. Similarly the production costs are valid only if four logistic modules, two habitability modules, two subsystem modules, and four payload module shells are produced.

Of the four basic modules, the most costly is the subsystems module, which provides the power, ECLS, station stabilization and control equipment, and the crew hygiene and waste facilities. The payload module costs (which are the lowest totals in Figures 28 and 29) are based on only the structural shell, external insulation, and meteoroid shield. For costing purposes, utilities were assumed to be "stubbed" into the payload module, but no internal distribution was included in estimating its costs.

The annual funding distribution plots for the development phase, the production phase, and the operations phase (excluding launch costs) of the baseline concept are presented in Figure 30. In addition, the total annual expenditure curve is also presented.

The initial higher level of expenditure during the operations phase reflects the expenditure for operational spares, which are produced before the production lines are shut down and are then stored until needed later in the program.

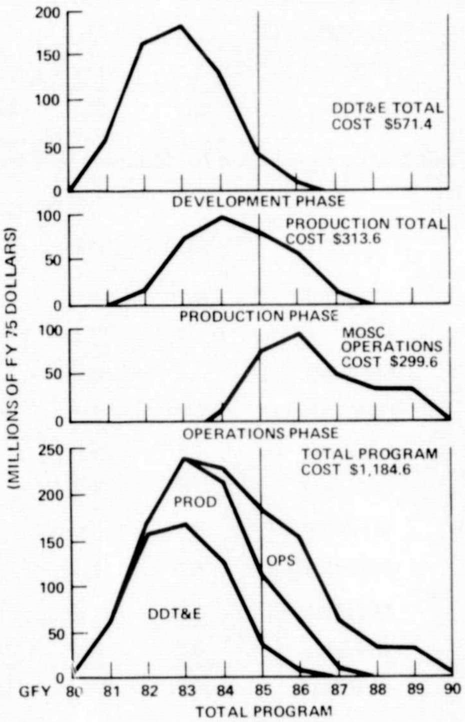


Figure 30. Baseline 4-Man MOSC Facility Annual Funding Distribution

To provide a frame of reference for assessing the operational effectiveness of the baseline MOSC system, 230 of the 725 Shuttle flights identified in the 1973 Space Shuttle Traffic Model (see Book 2) for which stay times in orbit beyond 7 days are preferable, were used for a comparative evaluation of 7-day Spacelab and extended-duration MOSC operations. These 230 flights involved only 42 payloads but all 42 were included in the 19 payload groups utilized in the MOSC analysis. The 230 flights were programmed over an 8-year period in earlier mission models. Therefore, for comparative purposes only, the program costs for these alternative payload implementation programs were based upon an 8-year period, 1985 through 1992.

Of the 7-day Orbiter-Spacelab launches/flights, 230 would be required to provide approximately 58,000 manhours necessary to accomplish the research objectives of the 42 payloads. By contrast, during this same 8-year period,

two MOSC facilities, one in polar orbit and one in a 28.5° inclination orbit, would nominally require only 68 support launches (two Shuttle flights to launch each orbital facility plus eight logistics flights each year for 8 years). Although this 8-year MOSC program would provide over 77,000 working manhours in orbit, only 38,000 manhours would be required (assuming an 85% learning curve) to perform the tasks requiring 58,000 manhours in the 230 flights operating in the sortie mode. The 39,000 surplus manhours in the MOSC program would be available for other activities and to support additional payloads as they are developed.

Figure 31 presents the cumulative operational costs for performing an 8-year program with MOSC and with the Spacelab. Assumptions upon which the comparison was made are (1) identical experiment programs, (2) identical payload costs, (3) Shuttle launch costs at $12.2 million per launch, (4) no development costs for Spacelab due to European support, and (5) MOSC total project costs of $1,184.6 million. On the basis of these results, it can be seen that there are significant cost advantages to using the MOSC approach as compared to the alternative (with an identical experiment program). An extended-capability MOSC program encompassing 68 flights would total $2.06 billion as compared to $2.81 billion for the Spacelab.

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	TOTAL LAUNCHES	BILLIONS OF FY 75 $	REMARKS
SPACELAB	230	2.81	
MOSC	68	2.06	LAUNCH ON 90-DAY CENTERS 2 FACILITIES (POLAR AND 28.5°)

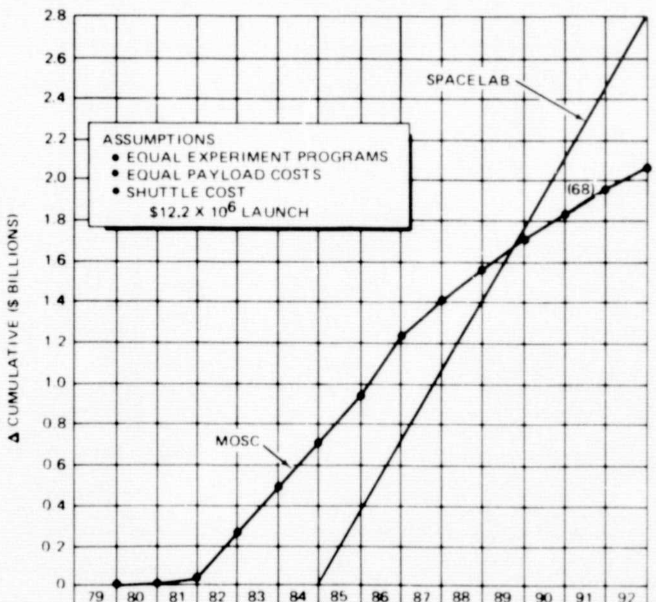

Figure 31. Operational Cost Comparisons

Section 5
CONCLUSIONS

In order to provide proper perspective and to maintain a sense of proportion in advance design studies, it is believed helpful to consider, in scenario form, the alternative courses of action and the objectives that singly or in combination represent future space initiatives (Figure 32). In the area of manned space systems specifically, long-term objectives will compare eventual manned planetary missions, lunar bases, space colonization, and permanent Earth-orbital space stations, including facilities in polar and geosynchronous orbits. The role of the systems planner is to develop a plan that will lead to these long-term goals in the most expeditious manner, taking into account the real-world constraints and conflicting demands of financial, technological, and manpower resources. The purpose of the MOSC Study has been to examine one step in this overall scenario—that of extending the presently projected capability circa 1980 to longer-duration missions through the more effective use of man and his capabilities, and to do this in a logical and cost-effective manner. The concepts described on the preceding pages can fill the need for a realistic and cost-effective evolutionary approach to expanding man's presence in space.

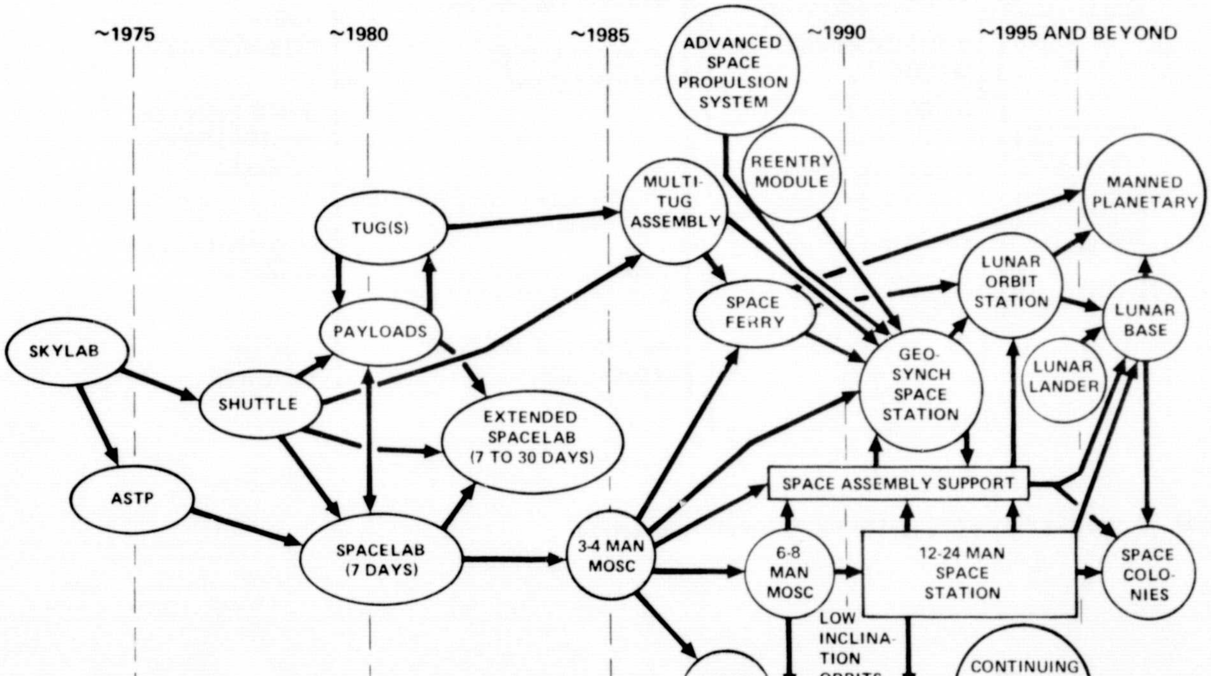

Figure 32. Space Systems Scenario

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The planning and development of future space programs cannot be done in isolation from the many critical problems facing the peoples of the world during the coming decades (Figure 33). There will continue to be many conflicting and competing demands for resources in the years ahead. The continued population growth will remain with us for the foreseeable future; and even if the population growth were zero, the human desire of each individual to increase his or her standard of living would be a major forcing function in accentuating the criticality of the already pressing problems being faced today.

While the baseline facility derived in the MOSC Study and future manned space programs will not solve all the world's problems, significant contributions can be made to the solution of many. The research and applications areas that are directly related to current world needs are the ones that should be emphasized in current space planning activities.

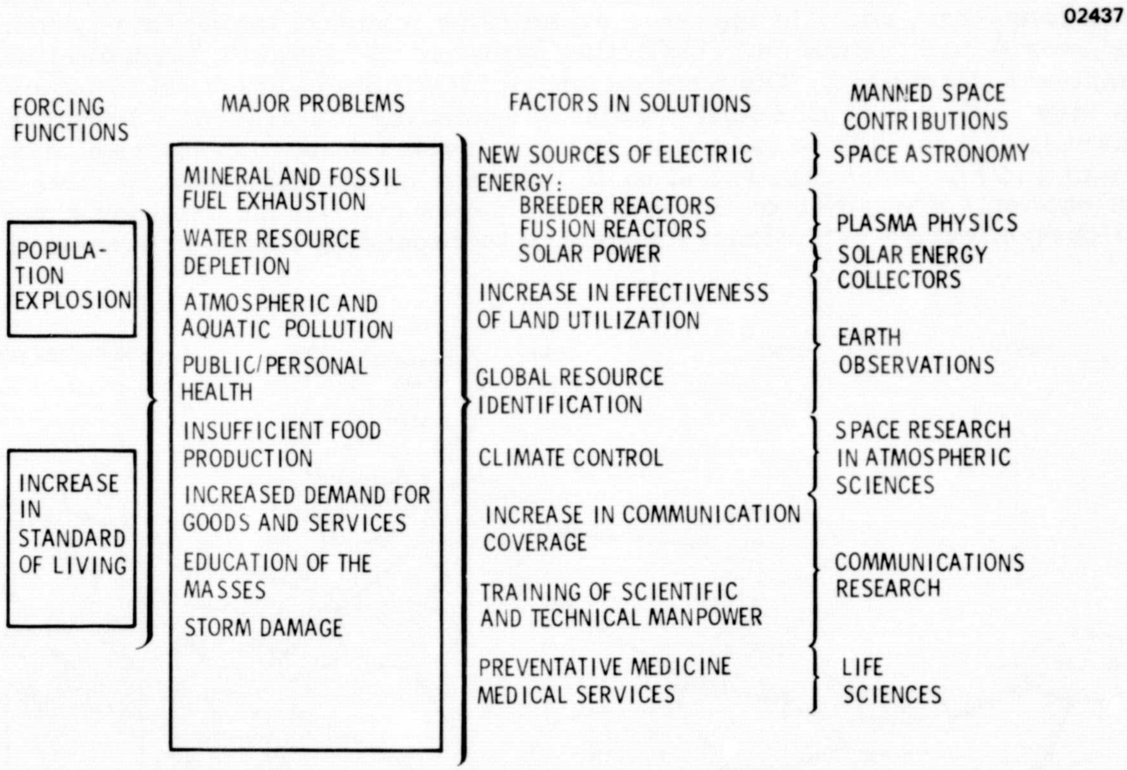

Figure 33. World Needs and Manned Space Research/Applications

In summary:

- A continuously manned orbital facility provides a platform for research applications and implementation, including the assembly of large structures, space manufacturing, etc.

- A free-flying facility as defined in this study appears to be the most cost-effective way to provide a continuing manned presence in space.

- The anticipated world problems of the 1990's must be faced and solved in the 1980's. An extended-duration manned orbital facility can make significant contributions to their solution.

Weighing the requirements for a broad, space-based research program against a general scenario of likely future space activities, and realistically considering the financial and technical constraints that bound the rate of growth of future space systems, an evolutionary program is proposed. Such a program would be predicated upon the successful implementation of the Shuttle/Spacelab activity and would call for the development of 4-man, permanently manned orbital facilities that would serve as basic building blocks providing growth options to larger 12- to 24-man space platforms when demand and support dictate.

It is recommended that the development of 4-man permanent facility capable of supporting space activities in a low-inclination, low Earth orbit, or in a polar orbit, represent the Nation's next major initiative in space.

As the most feasible pathway to orbital operation crystallizes, the interactive nature of payloads and facilities require that research scientists and applications specialists also continue to reexamine the requirements that they in turn wish to impose upon the evolving orbital facilities. It is often possible to modify research protocols and operational protocols to work within the capabilities of specific systems while still achieving the desired objective. A continuing dialogue between the research scientist and the system designer should be encouraged, so that the optimal solution is achieved for user and designer alike.

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